

# ROADS and STREETS

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HALBERT P. GILLETTE, President and Editor  
E. S. GILLETTE, Secretary

R. W. HUME, Vice-President  
C. T. MURRAY, Managing Editor

Cleveland Office, 621 Hippodrome Bldg.: E. C. KELLY, Manager  
New York Office, 415 Lexington Avenue: ERWIN T. EYLER, Eastern Manager

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## The Risk Involved in a Change of Quantities

Risk is one of the outstanding features of contracting. All contracts involve some risk. Some involve a good deal of risk. Some of the risks are rather apparent, others are not as well understood. Among these latter is the risk of having the amount of work reduced or its nature changed—a risk that is innate in all unit price contracts.

Recently a case of this kind, quite illustrative of the nature of this sort of risks, came to the writer's attention. The contract was a small one—only 6,000 yds. of excavation was involved, but it serves to show what the effect of radical changes in the nature of a job may be. The contract involved the removal of rather a stiff clay from a ditch—a channel change—incident to the construction of a highway. Original plans called for an 18 ft. bottom width with  $\frac{1}{2}$  to 1 bank slope. On this basis the work was sublet to a contractor who was at that time working in that neighborhood. The price agreed on was 21 ct. a cubic yard. The equipment available consisted of a plow and a number of 4 ft. fresnos and while the haul was rather long, the price being considered, it was thought that wages, team cost and a little profit could be made. After the arrangements had been completed a rather temporary camp for a small outfit was put up and work was begun, but no sooner had work started than the plans were changed so that the 18 ft. bottom was reduced to a 10 ft. bottom. As a result of this it was found that during the greater part of the job the working space was so restricted that the fresnos had to be stopped when the plow team was at work, as the plow team and the fresno teams could not pass in the space available. As a result of this the time required for taking out the reduced yardage—about 4,200 yd. were involved in the modified project as compared with 6,000 yd. in the original design—was somewhat greater than it had been estimated would be required for the 6,000 yd. contained in the project as originally designed.

In short the cost was as great as though the whole 6,000 yd. had been handled but the price received was only about two-thirds of that originally agreed on. The difference—about \$400 was more than the profit in the job. It was a small job but quite illustrative of the effect occasionally met in a change in plans.

A somewhat similar case that came to the writer's attention a year ago involved changes in the plans for a number of small concrete culverts. The subcontractor had taken these at a low figure as they were all of one or two sizes and he planned to use each form a number of times. He had made no profit on the job because an engineer who liked skew culverts and had had most of them built in this way in spite of the fact that the plans skewed none of them—a course which required a complete rebuilding of the forms for each culvert. As a result a summer's work

which should have been profitable had caused much worry and paid only scant wages.

In both of these cases failure to make a profit was to be laid to changes in plans which had rendered the execution of the work more difficult. This is almost unavoidable in unit price work. It may be reasoned that the contractor is not, in such cases, bound, as the nature of the work is so much changed that he cannot be held to perform it. This may or may not be the case. In the case of the ditch, the work could not have been easily avoided as the engineer could have claimed that with some other form of excavation equipment the work might have been rendered more easy of execution rather than more difficult. With the concrete culverts a better case could have been established but even here, avoidance of responsibility might easily have been attended with difficulties perhaps as expensive as the execution of the work. The point is that changes in plans, even when they seem simple and even trivial, may cost a contractor a good deal.

Even more money is often lost by reductions in the amount of work though the changes do not complicate the work. Take a simple illustration—a job for which in its original form the estimate was as follows:

For Project A—60,000 cu. yd. steam shovel work—	
Moving shovel to job and out again to railroad.....	\$3,000.00
Establishing camp and bringing other equipment.....	1,000.00
Breaking camp and getting stock to winter quarters.....	500.00
Actual cost handling dirt.....	12,000.00
Depreciation (shovel and other equipment).....	5,000.00
Profit.....	5,000.00

\$27,000.00

Bid price.....45c

During construction the amount of work was reduced to 40,000 cu. yd. with the result that as no other work was to be had for the shovel that season, the year's depreciation had to be carried by the work done. As a result of the change in plans the contractor was paid for his work—\$18,000.00—against which he had to charge

Moving shovel to job and out to railroad.....	\$3,000.00
Establishing camp.....	1,000.00
Breaking camp.....	500.00
Wintering stock.....	500.00
Actual cost of handling dirt.....	8,000.00
Depreciation.....	5,000.00

Total.....\$18,000.00  
Profit.....0000.00

No exaggeration of the facts is involved in the statement that engineers who "save" money by reducing quantities in this way do contractors an outstanding injustice. It is not enough to contend that quantities are increased as often as they are decreased, for even if they are, there is no assurance that the unexpected profit which results will go to the man who, by this process has been deprived of all profit on some other job.

Changes in plans—particularly those which result in "savings" in quantities—are a confession of the inadequacy of the preliminary work. They seldom are necessary and because of the really violent effect they may have on contractors' profits, should be opposed at all times and permitted only under most exceptional circumstances.

## Rail Sections for Street Railways

To the Editor: On Pages 201 and 202 of your May issue of Roads and Streets I note an article by J. I. Catherman, Engineer Maintenance of Way, Illinois Traction System. In discussing the subject of rail, Mr. Catherman states "one of the greatest blessings that could come to the railway industry would be a committee of our railway organizations with courage enough to set forth specifications covering a few types of rails, rails that would take care of any kind of traffic and under any kind of conditions, and added to them manufacturers who would say 'we will roll these rails and no other.'"

If Mr. Catherman will refer to his copy of the Manual of the American Electric Railway Engineering Association he will find that the first part of his requirement has already been met. Committees of the railway industry representing both the user and manufacturer have during the past few years devoted a considerable amount of time to this problem and have already accomplished what he suggests as desirable. There are now two sections of grooved girder rail (one 7 and one 9 in. in height) weighing 122 and 134 lb. per yard which have been standard since 1913, and in addition an existing lighter 7 in. grooved girder rail weighing 103 lb. per yard will probably be standardized by the A. E. R. E. A. this year to meet the requirements of the smaller properties with lighter rolling stock and more infrequent service. Incidentally it might be mentioned that the use of the A. E. R. E. A. 7 in. standard sections has now reached the point where they comprise more than half the total rolling of 7 in. grooved girder rails by one manufacturer and more than three-quarters that of the other. There are also three sections of 7 in. plain girder or high tee rails weighing 82, 92 and 102 lb. per yard respectively which have been standardized by the A. E. R. E. A. These three plain girder rail sections as well as the two grooved girder rails first referred to above, have also been adopted as American standard designs by the A. E. S. C. In addition the American Electric Railway Engineering Association has also adopted as recommended designs three sections of so called standard tee rails, i. e., the 80 lb. A. S. C. E. and the 90 and 100 lb. A. R. A.-A rails.

This gives a total of eight sections which have been standardized by committees of the electric railway industry. These committees have included in their personnel the best engineering talent the industry possessed. The fact that all five sections which are essentially designed to meet street railway conditions have been adopted as American standards, speaks for itself. It is felt that there is no con-

dition of street railway traffic which cannot be satisfactorily met by one or another of the above eight sections. The trouble has been to get the individual engineer to "see his problem as others see it."

As regards the second half of Mr. Catherman's hypothesis is concerned, we should not lose sight of the fact that the rail manufacturer is in business for the same ultimate purpose as any other firm—to make money. While it is reasonably certain that he would very much prefer to have only a few rail sections to roll and does discourage the rolling of obsolete sections and the development of new sections unless he is assured that the latter will replace existing designs, it must be remembered that he generally does so reluctantly and only after the purchaser has agreed to pay the extra manufacturing costs involved, the premium for meeting the ideas of the individual. If the truth were known it would be found that the blame for the situation which exists lies entirely with the engineer. It could not be expected that the manufacturer would refuse to accept such business when it can be secured on terms which will assure him a profit. If more use were made by today's engineers of the past experiences of their predecessors the cause of standardization would be much further advanced than it is and this does not mean that all further development of a given product or process should cease. However, it is a situation and not a theory which we have to face and as long as men continue to be so constituted that they can only see things their own way, just so long will we be up against the "57 varieties," not only in the rail manufacturing industry but in many other fields as well. But Mr. Catherman must admit that the girder rail situation shows a marked improvement over that which existed 15 or 20 years ago as regards the number of rail sections available.

### HOWARD H. GEORGE,

Chairman, Committee on Way and Structures, American Electric Railway Engineering Assn.

**Iowa Counties Have Voted \$49,100,000 of Road Bonds.**—Forty-one counties in Iowa have voted county primary road bonds to the amount of approximately \$49,100,000, and these counties contain over 50 per cent of the population of Iowa. It is expected that by fall two-thirds of the counties will have voted bonds to the amount of nearly \$66,000,000.

**Spain to Spend \$72,000,000 on Road Work.**—A Spanish Royal Decree authorizes the expenditure of 409,000,000 pesetas (\$72,150,000) for resurfacing 2,486 miles of highway, of which 1,448 miles must be completed within two years.

## Construction Details on Pennsylvania Highway Work

Samuel Eckels, Chief Engineer, State Department of Highways of Pennsylvania, has issued the following instructions to division engineers, district engineers and contractors regarding construction details:

The most essential details are the construction of embankments in accordance with the specifications in their fullest interpretation and full compaction of the backfill in culvert and other trenches as well as the fills adjacent to structures.

The greatest possible care must be used in the preparation of the subgrade, and it must be understood that the specified depth of the pavement is the minimum depth permitted. The backfilling with loose material between the forms may be permitted only when it is thoroughly compacted.

The bedding, setting and staking of the forms is a most important part of the work. The forms shall not be blocked up and fill placed afterward. The specification requirement of rolling 1 ft. in width on either side of the pavement area to support the form must be carried out. Where soft material exists under the forms, it must be removed and replaced with dry material, or if necessary, the forms shall be supported by a hub set under the form at each stake under the edge next to the pavement, and at least two additional hubs for each length of form driven to support the outer edge. Stakes of ample length must be driven in each specified stake pocket and wedged tight.

The greatest possible care must be used in storing and handling aggregates to keep them clean and segregation avoided or corrected.

The reinforcement in concrete pavements must be placed at the specified depth below the surface and the inspector and his superiors shall check this item of work by digging through the surface of the pavement after it has been struck off, and if a variation of  $\frac{1}{2}$  in. or more from the specified depth is found, the condition shall be corrected and the steel placed at its correct elevation.

The amount of finishing and manipulation of the surface shall be reduced to a minimum and wherever a flotation of thin, soupy material is flushed to the surface by the finishing operation, it will be considered evidence that the mixture is too wet or that too much finishing is being done. Such soft material shall be removed from the pavement and not worked over the concrete surface. The contractor shall straighten the surface and correct surface irregularities promptly and completely.

The specification requirements for the curing of concrete surfaces shall be carried out to the fullest extent practicable, and shyness in depth of covering material or insufficient wetting will not be permitted.

# Retiring War Time Road After Ten Years Service

How Roosevelt Road, in Cook County, Illinois, Is Being Torn Up and Repaved as Modern Super-Highway—Breaking the Concrete—Removing Broken Slabs—Grading Methods—Construction Camps.

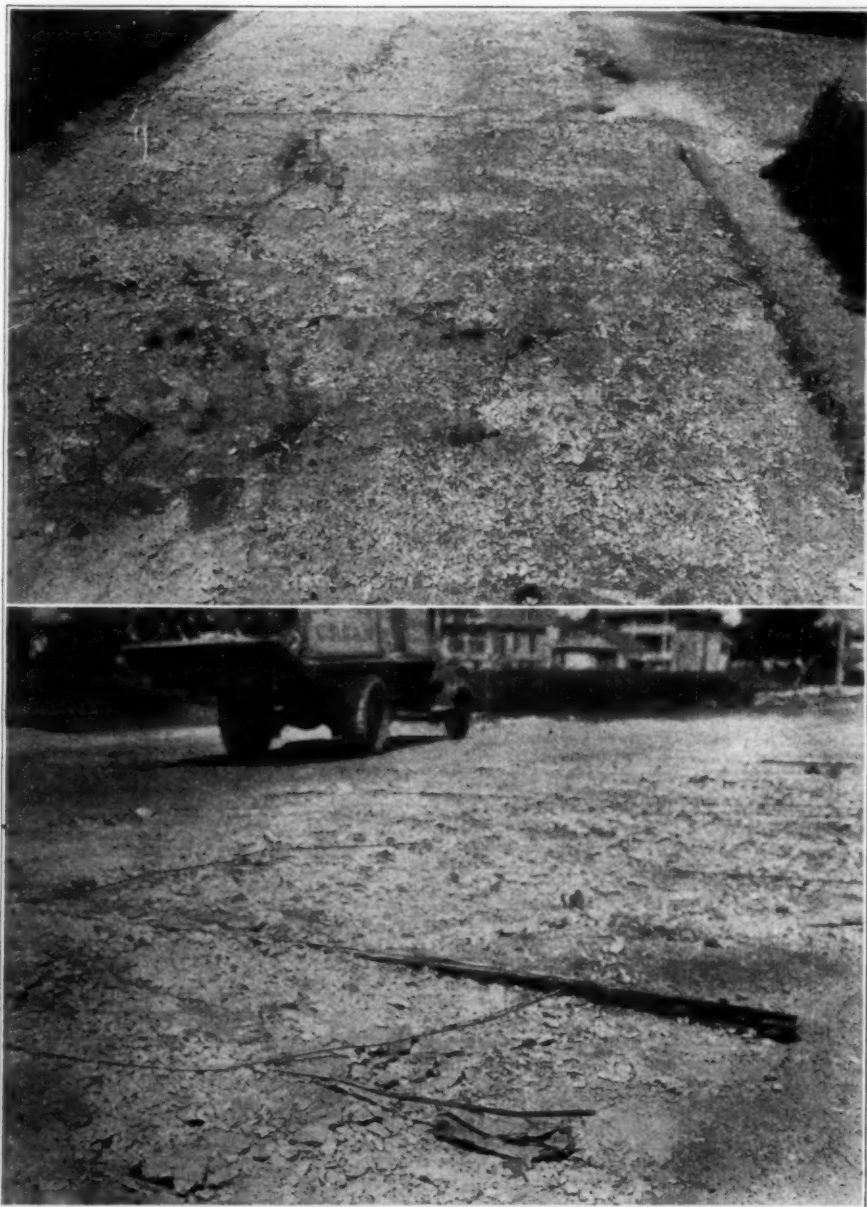
Just before, during and just after the World War, the State of Illinois paved Roosevelt Road out of Chicago with an 18-ft. concrete pavement according to the practice of that time. Hardly had the first two sections been opened when the military situation called for a heavy truck traffic over this new highway from the army base in Chicago to a nearby army camp where new units were being formed. The trucks loaded with equipment and supplies for this citizen army, traveling at a high rate of speed, subjected the pavement to serious overloads, according to stories that are now told. Then came the post-war rapid increase of motor transportation and this main artery was taxed beyond the limit that had been set by the designers. Now, after more than ten years of unusually heavy traffic, the highway has become worn out and must be replaced. How this work of repaving, and conversion into a 40 ft. super-highway, is progressing will be of general interest. Too, the comparison between the original section and the design of the new pavement will demonstrate the advances that the last decade has seen.—The Editor.

Way back in the years, when the world was at war and the art of concrete paving was yet young, states were building roads with the greatest thickness at the centerline, and tapering off toward either edge. Various expansion joints at a number of spacings were being tried out, and what little reinforcing was used was in the form of bars running transversely across the pavement, at right angles with the center line. Today, accepted practice varies rather radically with the practice of a decade ago. The Bates section, wherein the edges are thicker than the center, steel wire mesh takes a great deal of the tensile stresses in the slab and minimized cracking, edges are reinforced with bars parallel to the centerline, and wherein slabs are doweled together at expansion joints, is used in the state of Illinois and in several others, while other more modern sections are used by other leading states. These more modern sections, evolved on the basis of observation of older highways, upon the basis of test roads, and upon the basis of exhaustive laboratory research, bear promise of success.

It will be of general interest, therefore, to examine one prominent highway of a decade ago, to see its present condition after exposure to modern traffic conditions, and to observe how such a highway is now being torn up and replaced by a modern super-highway designed and constructed in accordance with today's accepted theory.

**The Old Road.**—Roosevelt Road, a prominent state highway extending

from 12th Street or Roosevelt Road in Chicago, and running out from that city through Cook County, Illinois, was paved with concrete in 1917 by the Illinois State Highway Department. The work was done under contract in three sections. The first was paved in 1915 about 10,000 ft.; the second in 1916, to a length of over 15,000 ft., and the third section was paved in 1919. This last section was but a short one of 920 ft. The work was done by three



Upper—The Hammer Broke Up the Unreinforced Slabs in This Manner; Lower—This Is the Way the Hammer Left the Reinforced Slabs. Note the Steel and the Expansion Joint Brought to the Surface

different contractors. The total construction cost was about \$91,085. The following comparative costs prove interesting:

Sec.	Year	Length	Cost	Cost per ft.	Cost per mile
F	1915	10,047 ft.	\$38,010.45	\$3.884	\$20,486.40
J	1916	15,331 ft.	46,333.70	3.023	15,961.44
56	1919	920 ft.	6,741.43	7.327	38,686.56
*New	1927	30,015 ft.	176,264.59	5.872	31,004.16

\*Note: This is for the new 40 ft. pavement.

This pavement, badly needed to permit transportation of military supplies from the army supply depot in Chicago to the great army training center known as Camp Grant, at Rockford, Ill., had to be supplied in the shortest possible time. Designed according to the practice of the day, this highway was paved to a width of 18 ft., with rather wide earth shoulders, and in sections was paralleled with very deep ditches that tended to keep the traffic

on the pavement itself rather than on the shoulders. The pavement averaged 8 in. thick in the center, and tapered to 6 in. at the edge, as shown in the

drawing of the section used. The subgrade was flat. Greater thickness has been observed in some parts. In the portion running through the swampy ground just west of the Des-plaines River, the slab was reinforced with  $\frac{1}{2}$  in. deformed bars on 24 in. centers, running transversely the width of the pavement. On the higher ground to the west of the Indiana Harbor Belt Line this reinforcing apparently was omitted except at box cul-

verts and other structures, and at occasional low spots where a soft subgrade was encountered. Expansion joints were provided about every 30 ft. These joints were of the type consisting of a sheet metal strip with lugs holding it to the slab, and a bituminous filler poured between these two strips at each joint.

**Condition of Road.**—By 1927, this old pavement had about reached the limit of its economic life. Frequent patching had kept it in service for several years. Examination showed a prevailing crack running about on the center-line, one or two cracks normal to the center crack and equidistantly spaced between the expansion joints, together with the characteristic diagonal corner cracks at the joints, and an extensive raveling at many of the corners. These holes in many cases had been found to extend through to the subgrade, and in the reinforced section allowed the reinforcing to curl up from the concrete and project above the roadway. Some scaling and other signs of wear were observed at points along either edge. Investigation, however, indicated that the concrete itself was very good, and probably would develop a strength of as high as 5,000 lb. per sq. in. if placed in the testing machine. This fact was again observed when in breaking up the slabs the fractures were ordinarily found to run through the large aggregate, showing a good bond that developed the full strength of the aggregates. The actual specifications called for 1:2:3 $\frac{1}{2}$ , and the fractured concrete appeared to be well mixed in about that proportion. Maintenance costs were averaging \$2,300.00 per mile per year, and would have been even greater than that figure in 1927.

According to available records the subgrade was prepared by hand and rolled, the slab was hand tamped and belted, and curing was done by the earth and water method.

It might then be said, at this point, that the short life of the old pavement was possibly more due to inadequate design, because of a lack of usable data on future traffic requirements, rather than to faulty design or construction. It had but grown obsolete and unequal to the task put upon it by the great traffic that grew during the decade after the pavement was laid.

**The New Pavement.**—The state is now engaged in removing this old pavement and replacing it with a 40 ft. pavement of more modern design. The new standard section is illustrated herewith, with dimensions and reinforcing shown. For the most part this new pavement will follow the old, but all curves will be lengthened to 1,000 ft. radius, and the road will be relocated to the section line on the west end. Present work provides for 30014.98 ft. of this 40 ft. pavement.

**Breaking the Slabs.**—The first operation called for the removal of the old slab and such structures as box cul-



Lower—Breaking Up a Small Bridge. Note the 3000 lb. Hammer on the Cable From the Boom of a Crane, Lifting a Large Piece of Concrete Into the Truck; Upper—Closeup of Typical Broken Section, Showing Clean Fracture Through Aggregates, the Good Distribution of Aggregates, and an Impression Left by a Reinforcement Bar

verts have concrete 3,000 height used stick against It was means was u the cr latter the bo the fr thus of but 15 ning o done e the wo except ture of a powe during The ing on part b venient shovel blows o forcing the sur of the more a occur.

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verts and small bridges that would have to be replaced. To do this, the concrete was broken up by means of a 3,000 lb. hammer dropped from a height of 20 ft. The power shovel was used in this work. First, the dipper stick was run in until the dipper rested against the boom and out of the way. It was then lashed in this position by means of a chain. Next, the main cable was unreeved from the main shieve, the crowding cable unreeved, and the latter reeved over the main shieve of the boom. The weight was attached to the free end of the crowding cable and thus operated. This entire change took but 15 minutes each night at the beginning of the shift. The breaking was done each night for ten hours, leaving the work of removal for the day shift, except on one structure where the nature of the work called for the use of a power crane to operate the hammer during the day.

The blows of this heavy weight falling on the top of the slab for the most part broke up the concrete into convenient lumps of the right size for the shovel to handle. In some parts the blows of this hammer worked the reinforcing bars and expansion joints to the surface and almost completely out of the slab, but where the steel had more adequate coverage this did not occur.

**Removing the Concrete.**—After it was broken, the concrete was shoveled from the subgrade by means of a Northwest Gas Shovel equipped with a  $\frac{3}{4}$  yard dipper fitted with removable manganese steel teeth. The shovel gave best results when kept as close as possible to the work. The concrete is loaded by this shovel into 4 Hug trucks equipped with  $1\frac{1}{2}$  yard dump bodies, for removal to the dump. Progress averaged 400 lin. ft. a day, working a 10 hr. shift. The organization used on this part of the work included:

- 1 Foreman.
- 1 Shovel Operator.
- 1 Oiler.
- 1 Pit Man.
- 2 Dump Men.
- 4 Truck Drivers.

In cases where the concrete was found to be imperfectly broken and large chunks were found to be adhering to the bars, these were picked up by the shovel and deposited to the rear on the subgrade. Then a Holt 60, ten-ton tractor, with a heavy drag chain hitched to the rear axle, accumulated a load of such material on the drag chain, and this massive load was thus dragged to the dump. Chunks too large for the dipper or the truck, and not so connected with steel so as to permit handling with the tractor, were broken by hand and then loaded into the trucks. Steel was deposited alongside the road for future disposition.

**Rough Grading.**—After the old pavement was removed, the grading gang followed and brought the subgrade to

the desired section and grade within plus or minus two inches of the finished grade. To do this work, an Austin Contractors' Special elevating grader, equipped with a 36 in. carrier, and towed by a C. L. Best 60 ten-ton tractor, was used for the excavating. This elevating grader loaded the spoil into Stroud dump wagons pulled by 3-up mule teams. From 7 to 10 such teams were used on the job, depending upon the requirements of the day. While the average grading during the ten hour day amounted to about 700 cu. yds., on many a day this outfit moved as high as 1300 cu. yds. of the hard compacted clay subgrade and old earth shoulders. After grading, the subgrade was rolled with an Austin Pup roller. The grading gang consisted of a foreman, a tractor operator, a grader operator, and a skinner for each team.

At the time the job was visited, no fine grading nor paving had been started. This part of the work will be covered in a later issue.

**The Camp.**—While the job employed from 40 to 50 men at the time the work was visited, at least 200 men will be required when all operations are under way. Naturally, the provisions made for caring for the force would be of interest. The job is just outside a plentiful labor market, but the lack of rapid transit to parts of the work, together with the fact that the men put in a ten hour day instead of the eight hour day of the building trades in the city, made it advisable to establish a camp for the employees. Actually two camps have been installed; one for the grading crew and their teams, and another for all other men. The grading camp is located alongside the proj-



Upper—The Northwest Shovel Loading the Broken Pavement Into the Truck; Lower—This Cat Used to Snake Out Concrete Still Held by Reinforcing Bars



The Elevating Grader, Pulled by Tractor, Used for Rough Grading, with Several of the Three-Up Teams Used to Haul Away the Spoil

ect near the western end, while the main camp is located on 22nd Street, the next main highway to the south, and in the new subdivision town of Westchester. This camp is more centrally located.

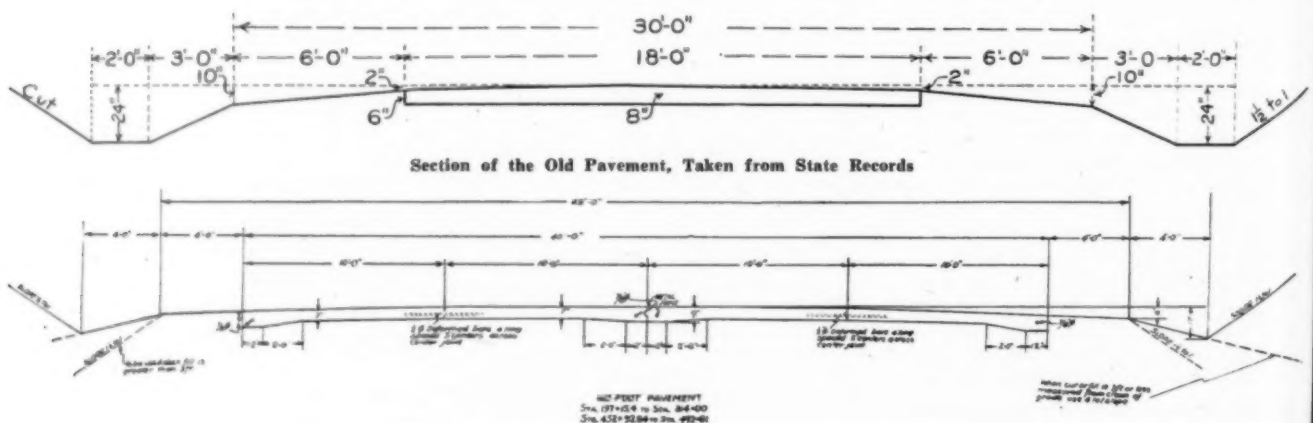
The buildings used were portable garages, 12 ft. by 18 ft. Double-deck steel bunks were installed at the rate of 4 to the bunk house. Thus 8 men could be housed in each house. One building was devoted to use as a kitchen and mess hall. In the kitchen, the food was prepared by one cook, assisted by three flunkies whose duty it was to help in the kitchen and wait on the tables. One dish washer was also employed. Small tables, each seating 8 men, were provided. Food was purchased at wholesale on the local market and delivered to the camp by the vendor. By this plan the board cost from \$1.00 to \$1.15 per day per man.

The grading camp is quite similar, except that stables are provided for the

teams. A stable hand cared for the mules and harness. Hay and grain were purchased locally. A blacksmith, sometimes with a helper, took care of the wagons and other equipment.

The work is being done for the State of Illinois by the J. J. Dunnegan Construction Co., of which D. H. Crawford is superintendent in charge of the job. The state is represented by G. N. Lamb, District Engineer; J. J. Frost, Resident Engineer; and by J. R. McCabe, Junior Engineer.

**Connecticut to Spend \$69,000,000 on Highways.**—The program of the State Highway Department of Connecticut for the next 4 years calls for the reconstruction of 137 miles of road in 1927, 362 miles in 1928, 585 miles in 1929 and 334 miles in 1930 and the construction of 550 miles of new highway. The estimated cost of this program is \$69,000,000.



Section of New 40 Ft. Pavement, Showing Major Features of This Modern Design

## Slow Truck Traffic on Narrow Highways

The two-lane highways carrying a heavy mixed traffic of automobiles and slow moving trucks are not economical from the standpoint of the auto driver, according to a report in May California Highways by E. T. Scott, Assistant Maintenance Engineer, Division VII.

To the individual motorist who has to check his driving speed when he overtakes a heavy, slow moving truck, to watch for a clear road ahead, or to let a car pass that approaches from the opposite direction, before he can pull ahead of the truck, the inconvenience and loss of time is but slight. However, this very small inconvenience that one slow moving truck causes one motorist, once in a while, becomes a considerable inconvenience when several thousand autos attempt to pass several hundred slow moving trucks on the two-lane highways.

Observations for this report were made on a stretch of highway in Los Angeles County, 9.5 miles in length, from traffic counts and observations extending over a period of two years, with the idea of determining if the loss in time and inconvenience would justify a higher maintenance cost in widening highways and eliminating obstructions.

It was found that the average speed of cars was 26 miles per hour and that of the trucks to be passed, 8 miles per hour. Time lost by each auto in waiting for an opportunity to pass a truck averaged 11 seconds. It was determined that there was an average of 1,227 "passings" per hour, which, multiplied by 11 seconds and reduced to hours, showed a loss of 3.75 hours to the motorists each hour, or 60 hours in the traffic count day of 16 hours.

Assuming that there are two persons in each auto and the value of their time is 25 ct. per hour and allowing 50 ct. per hour for auto rental the loss to the motorists is \$60 per day or \$21,900 per year in the use of the 9.5 miles of highway on which the observations were made.

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# Signal Systems for Control of Traffic

Problems of Signalling and Comparison of Various Styles Discussed in Paper Presented March 22 Before Michigan State Safety Conference

By HAWLEY S. SIMPSON

Traffic Engineer, Detroit, Mich.

The installation of one traffic signal or a complete system has in general been undertaken with the anticipated hope of instantaneous relief from traffic congestion, and a sudden and sure reduction in the accident toll. These hopes have not always been fulfilled in their entirety and very often the outcome has been the exact opposite; traffic has been retarded and the accident total has been increased.

But analyzed carefully, have these failures been caused primarily by faults inherent in the traffic signals, or are they due either to incorrect diagnosing of the disease, or to improper application of the remedy? To carry the medical analogy still further, the streets of a community are the arteries to which it owes its existence. The arteries are beginning to harden, they no longer have the flexibility required for comfortable circulation, and a remedy must be prescribed. But would a doctor prescribe for such a patient the entire pharmacopoeia? No. Neither would he give the patient all the drugs carried in his case. From them, he would select one, two or perhaps three, and if the physician's diagnosis is correct and the remedy properly applied, the patient is relieved. Such procedure has not in general been followed by cities in making traffic signal installations. Careful diagnoses of traffic movements have seldom been made, but because some particular type of traffic signal installation may have been more or less successful in another city, a complete system of traffic control signals is put in operation, and if the expected benefits are not immediately and completely realized, traffic signals of all sorts are condemned.

The point the speaker wishes to make is this: the traffic signal is not Aladdin's lamp. It is a man-made device which can accomplish certain things within a limited range; the degree of accomplishment being measured directly by the degree of careful study given to its proper application to the street system. More basic facts, particularly field surveys, and less of an effort to acquire a metropolitan air by attempting to keep up with the Joneses is the foundation upon which to begin a solution of the traffic problem.

**Public Should Understand Use of Signals.**—If these facts are combined with a real effort to educate the public in the use of the signal system, beneficial results cannot but result. A first-class typewriter is next to worthless in the hands of an inexperienced operator, and

likewise the best designed signal system is of little value if the public does not know how to make use of it.

It is possible on any street in Detroit on which the signal system to be explained later is in use, to drive through any set of signal lights without stopping if traffic conditions are normal, but the driver must understand the system and so drive that he conforms to the changing color characteristics of the signals, and not try to make the system conform to his desires. This can be done by driving slowly toward a red light, arriving at the intersection just in time to get the green light without being forced to stop. When driving through a group of green lights, the speed should be such as the law allows and if the system is well designed, a stop will not be required. And, in passing, it might be stated that promiscuous and unnecessary stopping is one of the greatest enemies of mobile traffic.

A very interesting handling of this problem is noted in Wyandotte, Mich., where the signal system is set for 17 miles per hour, and signs indicating this speed are posted at either end of the signalled street.

**Traffic Control and Traffic Regulation.**—The automatic traffic signal is a device for traffic control, as distinguished from traffic regulation. Traffic regulation promotes a safer and more orderly movement of vehicles and pedestrians by such means as parking restrictions, speed regulations, right of way rules, etc. In short, regulation consists of a variety of admonitions to the public that for the benefit of all, this or that action should or should not be permitted. A considerable degree of latitude is in general allowed in the compliance with traffic regulations and they may at times be interpreted by the individual as the then existing conditions seem to him to warrant. Many a motorist has violated the letter but not the spirit of a speed regulation by determining in his own mind what is a "reasonable and proper" speed considering the condition of the pavement, the volume and character of traffic and the condition of his own vehicle and this interpretation has often been sustained by the courts. By the same token, many motorists in the interests of their own and the safety of others, do not under abnormal conditions of weather and pavement, take full advantage of the permissive regulations.

Traffic control as differentiated from regulation is generally understood to include those restrictions upon traffic,

which are given by signals conveying a positive order to either stop or proceed, whether given by an automatic traffic signal or by other means. No latitude whatsoever can be allowed in obedience to traffic control signals and for this reason a stop and go signal must be placed and so operated that a strict compliance with its commands seems to the motorist at all times to be "reasonable and proper."

The nomenclature used in traffic signalling is at present considerably confused, and in order that we may all be of the same understanding, the speaker will describe each of the four existing types of traffic control systems, and identify each by one of its names which can be used consistently.

**Isolated Traffic Signal.**—The isolated traffic signal was the first used and is the simplest type of signal. It is a single signal located usually at a heavy traffic intersection and controlled by a timing unit commonly built into or located adjacent to the signal. The isolated type has no electrical connection with any other signal and operates as an entirely independent unit.

**Synchronous Control.**—The second type of traffic control is known as synchronous or as it has been termed, the "rabbit" type of control which covers a traffic movement consisting of a succession of high speed jumps followed by stops. Synchronous control of traffic signals is accomplished by grouping together on one street or in some one area under a central control, what would otherwise be a number of isolated signals. With synchronization of signals, all traffic at every controlled intersection moves north and south during one portion of the cycle, while east and west traffic is stopped. During the remainder of the cycle, the reverse is true and east and west traffic moves while north and south traffic is stopped. Such a signal system does not take into consideration the varying volume of traffic at the various intersections which it controls, but the timing must be based either upon the heaviest traffic in the group of intersections or upon an average value thereof.

**Partial Platoon Control.**—The third system is variously called the progressive, reciprocal, stagger, cascade, ripple, shower and wave method of traffic control, but which is a modification of the synchronous control, and in reality should properly be called the "partial platoon" type of traffic control, producing what its name implies, an approach to a platoon movement. A central con-



full 20-second red interval. Following the 11-second lane through, it reaches Alexandrine just about at the beginning of the red light and is delayed 18 seconds. Proceeding again on the green, the lane passes Canfield on the end of the green, is delayed 3 seconds at Forest, and passes through Warren again on the end of the green. The driving speed was 20 miles per hour, but the average speed was cut to 17.6 miles per hour due to the two stops necessitated by the traffic signals, the total delay being 21 seconds. The 29-second lane which was delayed 20 seconds at Peterboro, gets the "go" signal at Alexandrine, but runs full into a red light at

stopped for 80 seconds at four of the intersections.

Thus a single group of vehicles start at Temple, leaves Warren in four different groups. With these four possibilities for vehicles starting at the same point at very nearly the same time, is it any wonder that confusion exists and that remarks similar to the following are often made by motorists: "What in the h—l has our police department been doing to those traffic signals lately? Yesterday I went up Cass Ave. and only made one stop; today I drove the same street at the same speed and was stopped four different times."

record may thereby increase. The efficiency of the system for the law abiding motorist is low due to the repeated starting and stopping, and it is apparent that to increase the efficiency and minimize the tendency towards too high speeds, other methods of traffic control must be used. Previous to the installation of traffic signals on this street, such a study as shown here was prepared, and on account of the many obvious disadvantages of this timing, the signal lights were never operated synchronously.

**Partial Platoon.**—An approach to a more efficient movement on this street was obtained by use of partial platoon

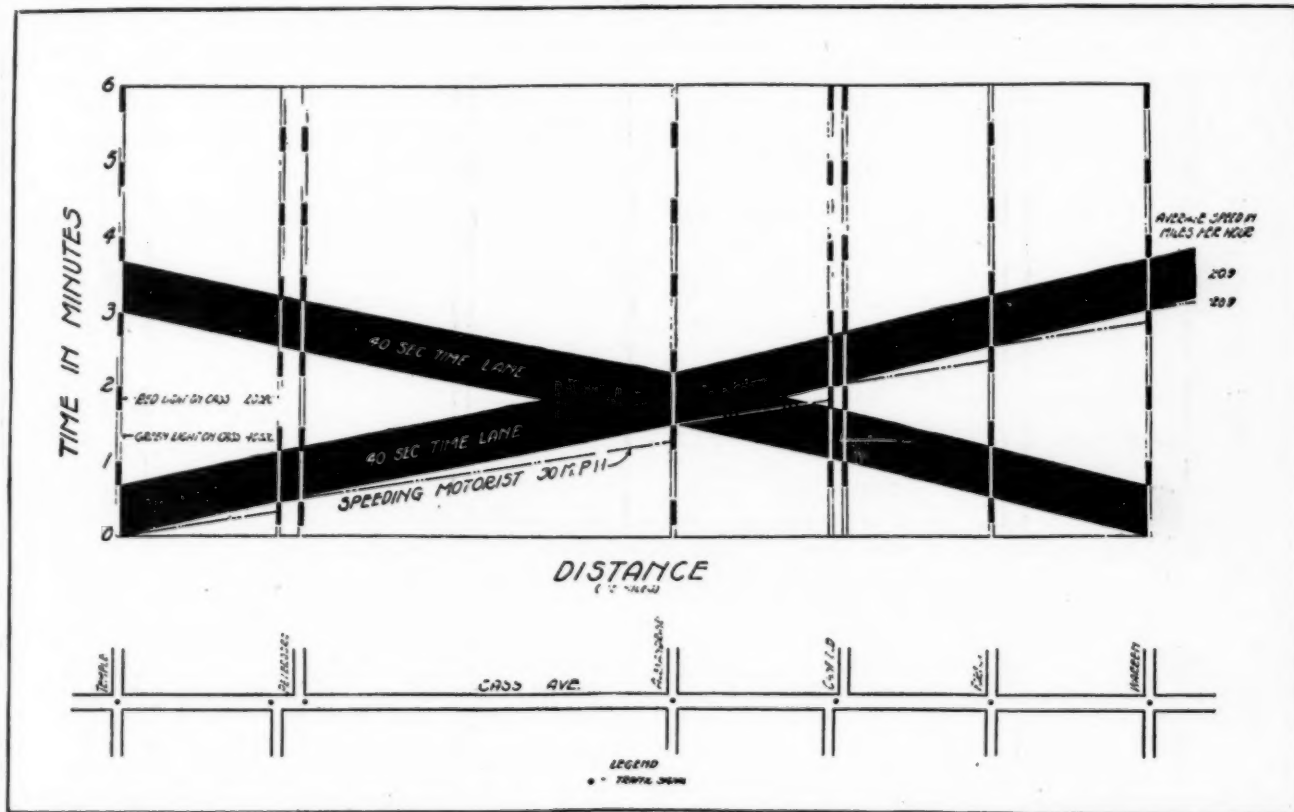


Fig. 2—With Partial Platoon System of Automatic Signals Applied to Same Area as Shown in Fig. 1, with "Go" 30 Seconds on Cass Ave. and Cross Streets, Running Velocity Becomes 17-24 Miles Per Hour and Average Velocity 26.9 Miles Per Hour, and There Is a Steady Movement of Traffic

Canfield and is further delayed 29 seconds. Proceeding to Forest Ave. this 29-second time lane is split into two parts, an 11-second lane which passes through on the green, and an 18-second lane which is stopped 20 seconds. The 11-second lane passes Warren after a 3-second delay, making an average speed of 15.4 miles per hour, the reduced speed being occasioned by the three delays totaling 43 seconds. The 18-second lane after being delayed 20 seconds at Forest reaches Warren, where an 11-second portion of the lane passes through on the green, making an average speed of 13.7 miles per hour due to the 3 delays totaling 60 seconds. The remaining 7-second lane is delayed an additional 20 seconds at Warren, making an average speed of only 12.4 miles per hour, after having been

These occurrences tend to demoralize the driving public, and the "smart" motorist begins to think up ways to "beat" the system. His first tendency is to try higher speeds with the discovery that the running time in the signalled area can be cut almost in two, an average speed of 26.9 miles per hour being possible when driving at 30 miles per hour with a possibility of only one stop as against two to four stops when driving at the legal rate of speed. The result is that a great many motorists driving through a synchronous light system tend to drive at the highest possible rate of speed, because the higher the speed, the less time the trip will consume.

Such a section of a street may become more or less of a race track by thus inviting speeding and the accident

timing of the signals, which is a diagrammatically represented on Fig. 2 in a manner similar to Fig. 1 except that traffic flow is shown in both directions. Partial platoon control means that instead of every signal showing red and green at the same instant, only every alternate signal shows green and the remainder red. This necessitates, of course, an even division of time for traffic movements in either direction at each intersection which in this case is 30 seconds. If this were not done and 40-20 timing used, there would be at Temple a timing of 40 seconds "go" and 20 seconds "stop," while the signal at Peterboro being reversed in color would show only 20 seconds "go" and 40 seconds "stop," such a condition of course, being impracticable.

With a 30-second time-lane, traffic can start at Temple Ave. and proceed north at a speed which may vary between 17 and 24 miles per hour, with an average of about 21 miles per hour and every vehicle will pass through the entire light system without a stop.

A group of vehicles entering the lane at either end emerges as a unit at the other end in all cases, and this holds true in every instance. Vehicles driving such a street always encounter similar conditions, and soon becoming accustomed to the timing, can easily conform to its requirements. The chart indicates clearly that speeding can only produce a succession of stops and waits.

Cass Ave. from partial platoon to platoon very shortly. The vehicle movements at that time will then be similar to those shown on Fig. 3. The latter appears to be very similar to Fig. 2, but the time-lane has been increased from 30 seconds to 40 seconds, immediately increasing the capacity of the street 33 1/3 per cent. The average elapsed speed is 20.9 miles per hour as in the partial platoon control and the average running speed between 18 and 23 miles per hour. As in the case of the partial platoon system, speeding can only produce a succession of stops and waits.

proposed for other cities will undoubtedly be watched with considerable interest.

Fig. 4 is a layout showing vehicular movements on this street if the platoon control were in use. Moving vehicles are denoted by arrows. Traffic on Cass Ave. is moving in each direction in three platoons each 40 seconds in length, with vacant space between, through which cross traffic can pass without in any way impeding Cass Ave. traffic such as is shown at Temple, Garfield and Warren Ave.

**Resume of Traffic Signal Experience.**—In order to justify the installation of one signal or a group of traffic signals,

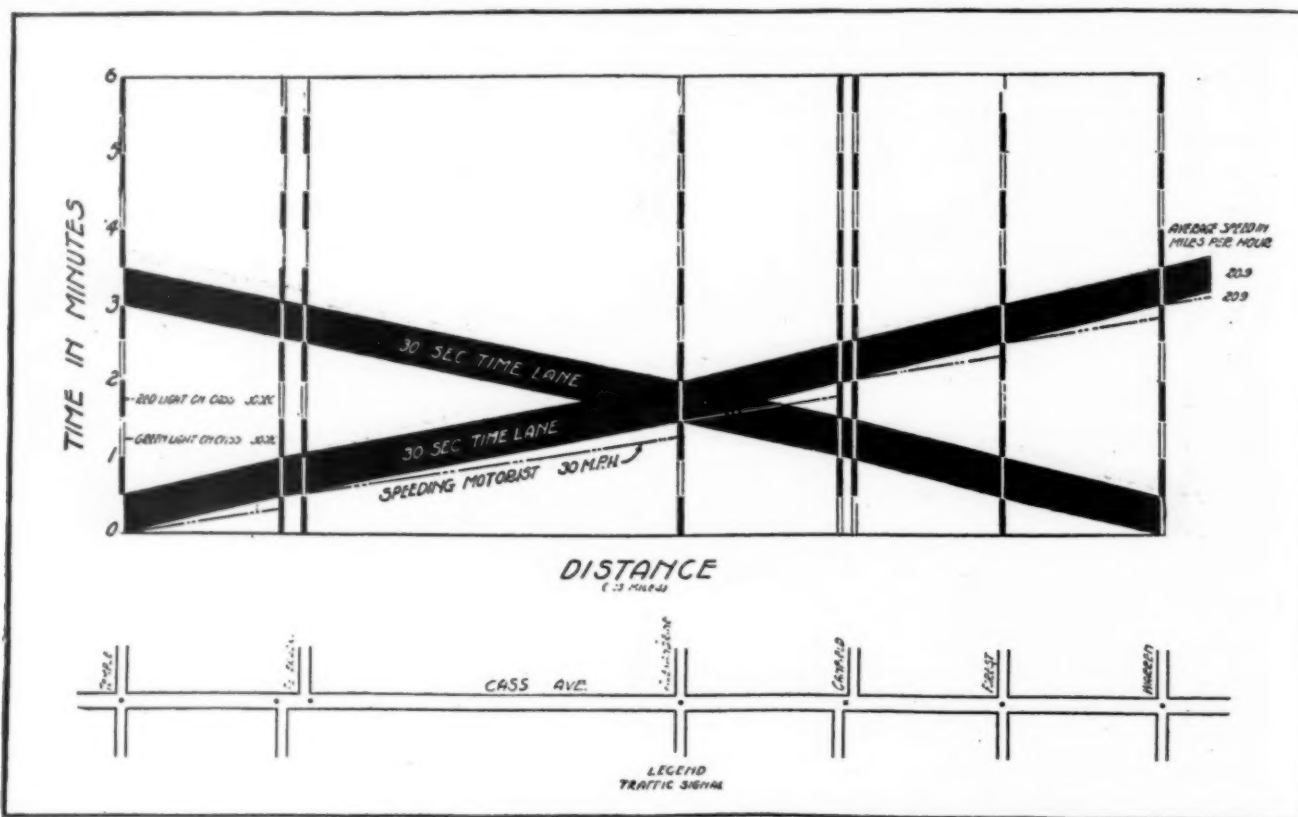


Fig. 3—Platoon Control System as Applied to Cass Ave. Increases Capacity of Street. "Go" on Cass Ave. 40 Seconds, "Go" on Cross Streets 20 Seconds, Running Velocity 18-23 Miles Per Hour, Average Velocity 20.9 Miles Per Hour

This type of control has a distinct disadvantage in that only one-half of the total cycle can be allowed for "go" on the main thoroughfare, whereas traffic counts show that on this street at least two-thirds of the cycle should be allowed for through traffic. It is felt, however, that this disadvantage is more than overbalanced by the beneficial advantages of the fluid traffic movement produced by the partial platoon control over the synchronous type.

As stated above, the partial platoon system is used on Cass Ave.

**Platoon.**—A much more efficient and fluid traffic movement can be obtained by use of platoon control, and the timing units to accomplish this have been constructed by the Police Department Signal Bureau and are now under test. It is planned to change the control on

If this average speed of 20.9 miles per hour should be found to be too high or too low, either at all times or during some portion of the day, the vehicular speed can be reduced or increased in whatever way riding tests show to be most suitable. Increasing the total cycle, thus allowing additional time between light changes, reduces the permissive speed, and decreasing the total cycle increases the permissive speed. The flexibility of this type of control and the potential increase of street capacity brought about by its use, is thus very marked and combined with the ability to change the timing of any individual intersection so that it most nearly fits the demands of traffic, produces what may very probably be the ultimate in traffic control. Such installations as that in Chicago and those

the following results should be obtained; namely:

1. Traffic must become more "fluid." By this it is meant that traffic must be passed through a street system with a minimum number of enforced stops and at the most efficient vehicle speed, which lies somewhere between 15 and 25 miles per hour.

To increase the vehicle flow to a maximum, it is becoming more and more apparent that traffic lanes should be established on the street, and so marked that weaving in and out, that is, driving first in one lane and then another, will be eliminated. If this division of a street into distinct lanes, which will reduce to a minimum what may be called "internal friction" is accompanied by a well designed platoon traffic signal control, it can reasonably

be expected of a street vehicle maximum street opening.

2. Traffic An additional control traffic, voted

regulation of traffic from automatic signal control, should be installed in a way that can even life, and officers' community may be signalling over in at certain all or part need for with the duties have now regu-

be expected that the vehicular capacity of a street may be increased from 800 vehicles per lane per hour—the present maximum assumed possible under ordinary stop and go regulation—to a figure approaching 1,200 vehicles per lane per hour. Increasing the efficiency of a street system by such easily and economically applied means as this, will postpone and may perhaps eliminate the necessity for expensive major street openings and widenings; and,

2. Traffic hazard to both the pedestrian and the vehicle should be reduced. An additional reason often advanced in favor of the traffic signal is that it reduces the number of men required to control traffic, that is to "stop and go" traffic, and allows their time to be devoted to the more important duty of

trians but no longer controls either. It is questionable if a single city has ever been able to reduce its traffic force by the installation of any number of traffic signals.

One of the earliest of synchronous control systems was placed in operation in an eastern city at thirty-two intersections covering the business section and was considered to be an outstanding example of this type of control. The customary promises of traffic relief was made and following its installation it was declared a complete success from the standpoint of increasing the vehicular flow, although, to the best of our knowledge, records of traffic flow were not kept either before or following the installation. Proceeding under our previous assumption that facts and not fan-

unofficial trial runs by automobiles were made at a speed of 9.8 miles per hour. Following the installation the same distance was traversed at a speed of only 6.4 miles per hour, a reduction in speed of 35 per cent. The use of synchronized signals necessitated lengthening the schedule of all street cars operating on Euclid Ave. In addition to the slowing up of street car movements, an increase in the peak power demand occurred, caused by the simultaneous starting of so many street cars, and resulted in an increased power demand charge being made upon the railway. Cleveland's reply however, to the same N. A. C. C. questionnaire was to the effect that traffic flow was expedited, although it is further stated that traffic records were not kept previous to the

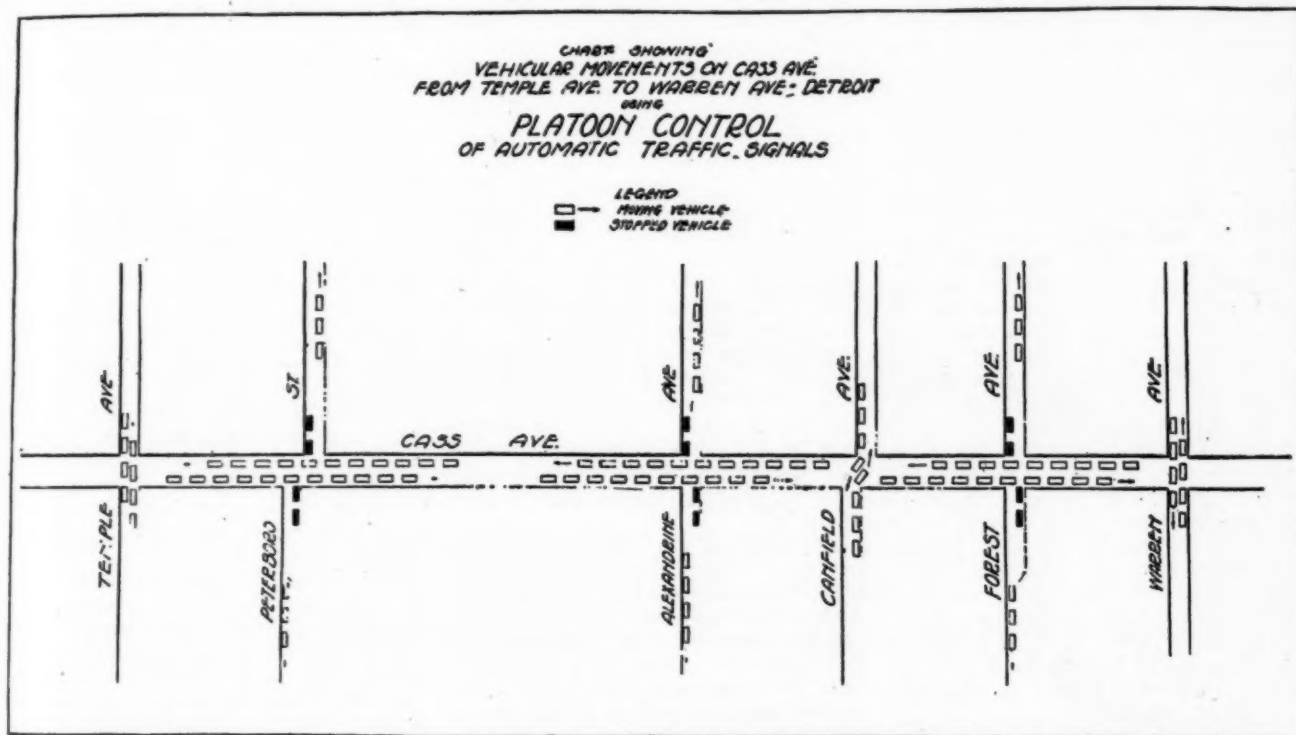


Fig. 4—Vehicular Movement on Cass Ave., Detroit, Using Platoon Control of Automatic Traffic Control

regulating traffic, thus affecting advantageous economies. If economies accrue from the installation of an automatic signalling system, these economies can be considered only supplemental, and considerations of economy should in no case be a fundamental factor in determining upon a signal installation. No amount of money saved can ever repay a municipality for a lost life, and no possible saving in traffic officers' salaries can compensate a community for unnecessary delays which may be brought about by injudicious signalling. Practical experience moreover in many cities has indicated that at certain intersections, either during all or part of the day, there still is the need for a traffic officer in conjunction with the automatic signal, although his duties have somewhat changed. He now regulates both vehicles and pedes-

trians are required, what are the facts? Rides made on street cars in this particular city and reported in the technical press show the speed of the same to have been reduced in the controlled district from 3 per cent to 12 per cent and a similar reduction would undoubtedly apply to free wheel vehicles.

In a bulletin of the National Automobile Chamber of Commerce\*, it was reported of the same city that accidents have decreased but accurate figures are not at hand, and we are therefore not in a position to comment on this phase of the situation.

**Experience in Cleveland.**—Acting largely upon the experience of Syracuse, N. Y., Cleveland installed synchronous signals at nine intersections on a section of Euclid Ave., about a mile in length. Previous to the installation,

signal installation. The facts in the case just mentioned refute the statement that traffic was expedited and prove just the opposite. Recently a clipping was received from a Cleveland paper which stated that they were shortly to change to what they call the "shower" control, and which we have referred to as the partial platoon. This decision was undoubtedly brought about on account of the evident inefficiencies of the system as demonstrated on Fig. 1.

The statement in both cities was to the effect that traffic congestion had been relieved, but in each instance and in the same questionnaire, reported that traffic flow records were not available either before or following the installation.

Cleveland has an accident reporting system, and frankly states that on the basis of the facts obtained therefrom, a

\*Issued May 10, 1926.

reduction in accidents has not occurred.

**Synchronous Control Reduces Fluidity of Traffic.**—In summarizing the results obtained where synchronous control is used, traffic flow has in general been retarded while opinion is about evenly divided as to whether or not the signal system produces greater safety. Synchronous control produces only a regular and orderly movement of traffic, but due to the fact that this movement is merely a regular succession of stops and starts, traffic fluidity is actually decreased. It has the further disadvantage that when installed at every intersection on one street, in order that a motorist may proceed any appreciable distance, traffic must be stopped on the cross streets for what may be an unjustifiably long period. This effect is exaggerated in New York upon Fifth Ave. where crosstown traffic is held from one and one-half to two and one-half minutes to allow Fifth Ave. traffic to move.

Synchronization places a premium upon speeding. The reckless motorist, knowing that a high rate of speed permits a continuous passage along the street, will take full advantage thereof while the law abiding motorist is actually penalized for obeying the law. The partial platoon and the platoon system equalize this speed differential to the extent that both classes must govern themselves in an identically similar manner with a consequent acknowledged reduction in the accident hazard.

The partial platoon type of traffic control is becoming more and more used and when properly applied is favorably received by the driving public. It provides for a fluid movement of vehicular traffic with the least number of enforced stops and furnishes a fairly high degree of efficiency in usage of street space. Such installations are in use in Washington, D. C., Minneapolis, Los Angeles and in Jackson, Wyandotte, Grand Rapids and Detroit in Michigan, to mention only a few.

**Conditions in Washington.**—The system in Washington as originally installed was synchronous, and operated for about two months timed on the basis of the traffic volume at Scott Circle where Massachusetts Ave. and 16th St. intersect. The timing cycle used was about 140 to 150 seconds, the extreme length being required to allow vehicles to proceed a reasonable distance before being stopped. The efficiency was low, and complaints were general. The Washington system was soon changed to the partial platoon control, using a cycle of only about 80 seconds, and providing for a nonstop movement on 16th St. of 22 miles an hour, the legal speed in the District of Columbia.

The shortened cycle, which cut the waiting time for cross traffic almost in half combined with the ability of vehicles to pass through the entire system at a reasonable speed has been sufficient reason for continuing to operate under partial platoon control, and not

synchronous as originally intended. In replying to the questionnaire previously quoted, Washington states that both traffic flow has been increased and the accident rate reduced by the signal installation. As Washington keeps both traffic flow and accident records, this information can be considered as authentic.

To cite an illustration with which all present are more or less familiar, the speaker will describe briefly Detroit's signal system. All four types of control are used on the 283 intersections handled by automatic signals, some intersections under isolated control, a few synchronized, the great majority operating as a partial platoon system, and one instance of platoon control.

An area roughly three-fourths of a mile square in the business district with 115 signalized intersections is under partial platoon control. This district is known as the traffic loop and is bounded on three sides by one-way streets, the purpose of which is to cut off and bypass traffic normally bound through the central district but with no necessary business to transact therein, by offering a convenient, safe and expeditious route around. The speed on the streets bounding the loop previous to the signal installation averaged 10.1 miles per hour. The average speed that can be maintained on these streets with the partial platoon control is 16.5 miles per hour, an increase in speed of 63 per cent. These values are taken from actual riding checks. The higher average speed is made possible not by increasing the running speed, but by elimination of stops, thus producing a higher degree of fluidity.

**Improvement in Detroit.**—With the existing partial platoon control, vehicles travel at a moderate and uniform speed, with a resultant saving in time, which not only produces economical operation but promotes greater street safety. Whether increased safety has or has not resulted, can be determined by an examination of the facts, in this case, accident statistics.

Table I gives the percentage increase or decrease of fatal and injured accidents in Detroit for 1925 over 1924. Table I gives the percentage increase or decrease of fatal and injured accidents in Detroit for 1926—when automatic traffic signals were in general operation—over 1925 when only a comparatively few signals were in service, as compared to the increase of 1925 over 1924.

Table I—Percentage Increase or Decrease of Fatal and Injured Accidents in Detroit

Year	Per Cent Increase or Decrease	
	Entire City	One Mile Circle
1925 over 1924....	48% .....	56%
1926 over 1925....	11% .....	*3%

(Traffic Signals in Operation.)

\*Decrease

In the city as a whole there was an average of 283 signalled intersection in 1926, and the lessened percentage increased of accidents in the entire city was very marked. In the one-mile cir-

cle, an increase of 56 per cent in 1925 over 1924 was converted to an actual decrease of 3 per cent in 1926. In the one mile circle are located 124 of the 283 traffic signals, and it appears that the greatest improvement occurred in the section with the greatest number of signals per unit of area.

In order to use such 1927 figures for January and February as are now available, the figures have been tabulated in a slightly different way, showing the percentage of the total fatal and injured accidents of the entire city which occurred in the one mile circle:

Table II—Fatal and Injured Accidents Occurring in the One Mile Circle as a Per Cent of the Total Fatal and Injured Accidents Occurring in the City of Detroit as a Whole (Assuming City Area Constant)

1924—16 %	(Traffic Signals in Operation).
1925—15 %	
1926—13 %	
Jan. and Feb.—1927— 9.5 %	(Traffic Signals in Operation).

This indicates a steadily decreasing ratio of accidents occurring in the congested area to those occurring in the entire city. Tendencies such as those just discussed are at least indicative that the loss of lives and property can be effectually checked when the problem is properly attacked.

The inherent fault of the partial platoon control is that the cycle must be divided evenly with the same time allowance for traffic moving on the minor cross streets as for that on the main thoroughfare, thus unduly restricting the heavier traveled street and unnecessarily favoring the lesser. This inability to treat each intersection individually is due to the single control unit being made to serve several intersections. Partial platoon control does however provide for a nonstop fluid movement of traffic, and generally produces results superior to the synchronous control. It can however be successful only after careful study is made of existing traffic flow and traffic speeds on the street or in the area for which such a system is proposed. Due to the ease with which a synchronous installation can be converted to partial platoon control, it is certainly worth attempting, and no loss is sustained if it cannot be made to function successfully.

To sum up the results achieved by this type of control in fulfilling the two requirements of a good traffic control system, it appears that the partial platoon control does relieve traffic congestion and does assist in reducing the accident loss.

**Results in Chicago.**—The latest development in traffic signalling is the platoon type of signal control, which was first put into practical application in the loop district of Chicago. Each signal at the forty-eight controlled intersections is timed in accordance with the actual volume of traffic per lane per street and so controlled that a motorist traveling at the rate of speed for which the system is set encounters only green

lights; the introduction of a sideral wheel the local vehicle by an 25 per also b in traf ence in ble d operati ing to tional acciden the pe was re 1926, a cent.

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lights; each signal opening just before the intersection is reached. The introduction of this signal system has considerably increased the average free wheel vehicle and street car speed in the loop, thus materially adding to the vehicle capacity of the business district by an amount estimated to be between 25 per cent and 50 per cent and has also brought about a marked reduction in traffic injuries similar to the experience in Detroit, but to a more noticeable degree. The system went into operation February 7, 1926, and according to a report published by the National Safety Council, personal injury accidents in the signalled area during the period from February 8 to July 8 was reduced from 210 in 1925 to 162 in 1926, a percentage reduction of 23 per cent.

The expense of installing the type of control used in Chicago is a deterrent to its installation in other cities, although the cost is doubtless warranted from an economic standpoint. The introduction of some inexpensive and simple mechanism by which existing systems regardless of their present control could be readily converted to the platoon type at a slight expense, would certainly induce other cities to install such a control. At least two different control units designed to operate platoon systems are now in process of development, and if successful, should materially aid in relieving some of the more serious congestion areas.

Other features than mechanical control of the signal system enter largely into its efficiency as a traffic mover and accident preventer; three of which are:

1. The location of the individual signal.
2. Use of the amber light.
3. Position of the "stop and go" indication.

**Location of Signal.**—Signals may be suspended, may be located on a pedestal either in the center of the intersection or throat of the intersecting street, or located on one, two, three or all four corners at the curb, mounted either horizontally or vertically. Each method has its advantages and disadvantages. The suspended signal is out of the traffic flow but has poor visibility, the center pedestal type is in the most direct line of vision, but obstructs traffic to some extent and hinders turning movements if they must be made around the signal. The signal in the throat of the street also takes up some pavement space, but is a very efficient regulator of turning movements, effectually blocking out the path of improper left turns. The curb signal has much in its favor, being plainly visible, especially if all four corners are signalled, but the expense is comparatively high and no regulation of turning movements is provided.

With these and other important considerations affecting each type of location, it is difficult to say that one or the other is superior. Standardization of

signal location is very important and a movement is now under way to accomplish this and if the many diverse opinions can be reconciled, considerable of value will be accomplished.

**Use of Amber Light.**—The use and abuse of the amber light merits attention and two serious attempts are now being made to overcome its attendant evils. Amber is a cautionary warning light and should be used as such and such only. However, in "stop and go" signalling, it has meant "stop" to stationary traffic and "caution" to moving traffic. With two meanings for the same color, neither has been accepted, and it has been translated by both classes of traffic into "go" with the resulting confusion and intersection accidents. To overcome this tendency, Buffalo has eliminated the amber in both directions entirely and is using two level signals, red and green, allowing the red to show in both directions between changes of traffic so that both lines of vehicles receive a positive stop signal. Buffalo feels that this has been so successful that new traffic signals with only two level heads are being ordered. Other cities are displaying amber only following the green light, thus giving a very necessary cautionary warning to moving traffic, while standing vehicles receive no indication of the change until the green light shows. The amber light can serve no useful purpose in the change from red to green, but does have a use in the change from green to red, to allow traffic moving in the intersection to clear and it appears that a color cycle with one amber eliminated will aid materially in solving this one problem, the cycle being green—amber—red—green, etc. One intersection in Detroit has been treated this way and to date has functioned more satisfactorily than previously.

**Position of Colored Lenses.**—The position of the colored lenses in the signal may not seem important at first glance. But to color blind persons, the number of which it is estimated compose from 4 per cent to 8 per cent of the population of the country, it is very important. Red and green are colors very likely to be confused by color blind persons, but if the stop and go indications are placed always in the same relative position in the signal unit, color blindness is not the hazard that it would otherwise be. Railroads have for some time appreciated the value of position signals, and street and highway signalling can well profit by their experience.

The location and timing of traffic signals is becoming more and more an engineering problem, for upon the degree of reasonableness of placing and timing depends the degree of obedience of the public to that signal. Over-signalling or unnecessary signalling breeds contempt for all signals, with increasing contempt for other forms of traffic control and traffic regulation, and the speaker would like to stress the fact

that before even a single signal is placed, careful studies be made to determine all the involved factors. Traffic flow per lane for every hour of the day must be determined, turning movement volume ascertained, accident records studied and the influence of street lighting, standing vehicles, nearby buildings, trees and other obstructions to vision considered. To illustrate, two examples are cited; one in which a signal was installed without engineering study and later removed, and one in which a signal was not installed following the study.

A downtown intersection handled by a traffic signal installed without study had both a heavy pedestrian and vehicular traffic volume. The intersection was continually congested and pedestrian accidents were frequent. A survey of the situation showed the larger percentage of the traffic to be turning movements, which must always cut one line of pedestrians who are theoretically crossing in safety with the green light. This assumption of added safety in the mind of the pedestrian undoubtedly caused his vigilance to relax, resulting in a bad accident record. On the basis of this analysis, the signal was removed, congestion appeared to be reduced and the personal injury record was cut in half, dropping from 0.6 of an accident per month to 0.3 per month.

A second intersection in an apartment house district was experiencing—according to one of the apartment house owners—an accident a day. Tenants were complaining of the frequency of accidents and at least one tenant gave as an excuse for breaking his lease that his wife could not stand hearing the crashes. The Accident Bureau's records showed that an average of 1.3 serious accidents were occurring a month. A survey was made, and the volume of traffic seemed to warrant the installation of a stop and go signal. Analysis of the accident record however showed that one out of the four possible directions of conflict produced 70 per cent of the accidents. Investigation during the day revealed nothing. Another investigation was made at night and an optical illusion was revealed, apparent only to motorists traveling in the direction of the greatest number of conflicts. The illusion was such that the roadway on the intersecting boulevard appeared to be 80 feet farther away than it actually was and motorists found themselves in the intersection before realizing that their vision had deceived them. Feeling that this, and not speed or volume of traffic was causing the accidents, a flashing warning beacon—a regulatory device, as opposed to control—indicating a dangerous intersection, was put in service and where previously there had occurred an average of 1.3 serious accidents a month, no accident had been reported in the four and one-half months since the installation of the beacon, and the same man who reported one accident of some sort every day now states that

minor crashes occur only about once a month.

Careful study of situations such as this will reveal more locations where regulatory signals of the type above used are required than those where control signals are needed. By reason of the less rigid requirement which regulatory signals place upon motorists and because compliance is entirely voluntary, a higher degree of observance can be obtained. But the moment an unreasonable and unnecessary signal is placed, the morale of the driving public is lessened just a little bit more, and there may come the one straw that breaks the camel's back. Give the motorist half a chance to regulate himself and the police will find that there is not the necessity for so much control.

To recapitulate, traffic signals, both control and regulatory, are valuable implements when properly used. Improperly used they defeat their own purpose, become a hazard breeder and traffic obstruction. Their degree of worth is dependent solely upon the degree of reasonableness with which they are located and operated. If more careful study is given to methods by which existing signals may be made more efficient and less time spent in finding locations for more signals, then traffic signalling will not fail. Most important of all—get basic facts and apply the remedy indicated. But because the remedy looks good, do not take the contents of the whole bottle at one dose. It is liable to be fatal. Decide on a program, and apply information derived from the basic facts logically, and the traffic signals will do their part and become valuable adjuncts of a well organized plan of traffic control and regulation.

### County Highway Officials Organize

The American Road Builders' Association has just completed the organization of a national County Highway Officials Association, a body of local road officials representing each of the 3,070 counties in the United States. The new organization will function similarly to the American Association of State Highway Officials, and will be known as a division of the American Road Builders. At its annual convention and road show, the county highway officials will have the advantage of the annual sessions of its parent organization.

The organization meeting was held at Washington on June 17th, at which time a constitution was adopted and officials elected. Thomas J. Wasser, Supervising Engineer of the Board of Chosen Freeholders, Jersey City, N. J., was elected first president. Four regional vice-presidents were elected. They are: Charles E. Grubb, Wilmington County Engineer of Newcastle County, Del.; Edward W. Hines, Detroit, Road Commissioner of Wayne County, Mich.; John Kirkpatrick,

County Judge, Wayne County (Benton), Kansas; and Stanley Abel, County Supervisor, Taft, Cal.

The constitution adopted resembles somewhat the code used by the American Association of State Highway Officials, and sets forth the purposes of the new association as those of standardization of county road building, maintenance and finance methods, dissemination and exchange of road information, and the stimulation of local road construction.

The need for a national organization of the sort just completed by the American Road Builders' Association through its Business Director, Charles M. Upham, has long been paramount in the United States. With 3,070 separate political sub-divisions constructing and maintaining highways without technical intercourse or standardization of methods, the waste of county or township funds has been inevitable. The expenditures under local agencies are approximately the same as those supervised by well organized state departments. The roads affected are in most cases thoroughfares of a peculiar nature, being all-important to the immediate district in which they were laid, but at the same time not handling sufficient traffic to justify the construction of the more expensive modern highway. This peculiarity makes the county problem of intricate importance, and emphasizes the necessity for technical standards of grading, gravelling, surfacing or otherwise improving the local road. Through such an organization as Mr. Upham has brought into being, a great deal can be accomplished, both from the standpoints of efficiency and economy.

The new association will start its good work immediately. Contact men will be appointed in each county of the United States, and report to various committees that will be formed by the present group of officials. The first reports will be delivered on County Officials Day at the Annual Convention and Road Show of the American Road Builders' Association. The latter meeting will be held at Cleveland during the week of Jan. 9th, 1928.

The committees to be appointed are those on Survey and Plans, Road Type Selection, Design, Contracts and Specifications, County Highway Construction, County Highway Maintenance, Bridges and Culverts, Materials and Tests, County Highway Legislation, County Administration, Standardization of Accounts, Construction and Maintenance Equipment, Publications, County Highway Finance, Traffic, Publicity and Special Committees.

In addition to the president and regional vice-presidents, a board of directors was elected. The members are:

Elected for one year: Charles W. Deterding, County Engineer, Sacramento County, Sacramento, Cal.; Jerry R. Zmunt, County Commissioner, Cuya-

hoga County, Cleveland, O.; J. T. Bullen, Parish Engineer, Caddo Parish, Shreveport, La.; Merl Breese, County Engineer, Luzerne County, Wilkes-Barre, Pa.; R. B. Preston, County Engineer, Norfolk County, Portsmouth, Va., and J. A. Bromley, County Road Engineer, Anne Arundel County, Annapolis, Md.

Elected for two years: J. L. Jones, Los Angeles County, Los Angeles, Cal.; B. W. Davis, County Engineer, Nash County, Nashville, N. C.; Otto Hess, County Commissioner, Harris County, Houston, Tex.; S. A. Green, Roads Engineer, Baltimore County, Towson, Md.; R. C. Hill, County Engineer, Sussex County, Georgetown, Del.; T. D. Pendegrass, Superintendent of Roads, Durham, N. C., and T. H. Baldwin, County Engineer, Laramie County, Cheyenne, Wyo.

Elected for three years: H. B. Keasby, County Engineer, Salem County, N. J.; E. A. Griffith, Chief Engineer of Roads, Allegheny County, Pittsburgh, Pa.; Charles A. Brown, Chief Engineer, Orange County, Orlando, Fla.; C. F. Winkler, Probate Judge, Greenville, Ala.; Thos. H. Madden, County Commissioner, Trumbull County, Warren, O.; George A. Quinlan, County Superintendent of Highways, Cook County, Chicago, Ill., and E. C. Qwillim, County Surveyor, Sheridan County, Sheridan, Wyo.

### Advocates Creation of a Federal Department of Public Works

The American Association of Engineers strongly favors the creation of a Federal Department of Public Works, and at its 13th annual convention held in Tulsa, Okla., last month, adopted the following resolution:

WHEREAS, the many and varied activities of the Federal Government are carried on by a large number of bureaus in the Interior, War, Agriculture, Treasury and Commerce departments, and by other agencies; and

WHEREAS, the present jumbled organization, which has developed in a haphazard manner through a long period of years, is imperfectly adapted to present requirements, resulting in much waste and inefficiency; and

WHEREAS, Presidents Harding and Coolidge have both requested Congress to remedy this unsatisfactory condition through a reorganization of the departments, and Congress has for several years been engaged in the consideration of bills designed to effect this reorganization; and

WHEREAS, the engineers and architects of the country have for many years advocated the establishment of a Department of Public Works in the Federal Government to administer all matters relating to public works; and

WHEREAS, the co-ordinated planning and construction of public works would lead to great savings in the expenditure of public funds and would be of economic benefit to the country through the stabilization of conditions in the building industry;

THEREFORE BE IT RESOLVED BY THE AMERICAN ASSOCIATION OF ENGINEERS, in convention assembled in Tulsa, Okla., this 8th day of June, 1927, that

We heartily endorse the movement for a reorganization of the Federal departments and the creation of a Department of Public Works to have charge of the design and construction of all public works, and that

We earnestly urge the Congress to continue its work in connection with the proposed reorganization with a view to the early passage of a satisfactory bill to carry the said reorganization into effect.

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# Financing the Paving Contractor

Abstract of an Address Presented at the 8th Annual Convention of Northern California Chapter  
Associated General Contractors of America

By L. L. ELLIOTT

Elliott-Horne Co., Los Angeles, Calif.

The business of making streets is a manufacturing business. It is nothing else. It is the putting together of material and the fabricating of a product for use. It is one of the very few manufacturing businesses in the State of California, where every bit of material which goes into the finished product is produced in the State of California; and where all the money stays here.

The purchase of bonds, of street improvement bonds, or any other bonds eventuating from these things is such that if I bid and pay for them at 10 o'clock in the morning, the money goes out and goes to the company, and goes to pay the local cement man, the local oil man, the sand and gravel man, and so forth; and at 3 o'clock in the afternoon it is back in the bank again and has done its day's work. There is no other line in the State of California in the matter of manufacturing work of which that same situation is true, hardly. It is a big, strong, necessary business in the State of California, and it has a tremendous volume.

Our estimates for the State of California for 1927 (and they are only estimates, of course) are based upon the best figures we can get together of work coming under special assessments (not the general highway work of the State, supported by bond issues from other sources) but the big contract work of the cities and counties under special assessments, will be about \$75,000,000 in 1927. Taking it by and large, as a manufacturing business that is a business of a very considerable volume.

We feel very strongly on that proposition, that it is one of the big, necessary, fundamental industries of the State of California. Then, on the other hand, after that work is done, the money has done its work and paid for this material, and so forth, differing again from almost any other system of any other thing in the state, the value of that money remains and is added to the total of the general value of the State of California.

Now, we claim that, owing to that situation, if you will visualize it in that way, the business of manufacturing streets and roads is entitled to as high a place in the business regime of the community as any business which is existent in the community, and deserves as careful attention, as careful credit and as careful business methods and as good a personnel as any other industry in the state.

**Stabilizing the Contractor's Credit.**—

Now, it has been the endeavor of most of the financial houses for a number of years to find ways to stabilize the method of extending credit to the contractor. But the contractor must do his part in that regime as well as the other man, because you cannot do things by compulsion. It must be realized by the contractors that it is as much of their benefit and more, to be able to assist in stabilizing the method of extending credit on work of this kind, as it is to the financing house which is going to carry that credit.

Whatever the costs be, you must ultimately remember they are not only the actual costs of operation, and the necessary margin of profit which must be added in order to allow the business to progress, but, added to that, must be the total losses sustained by reason of unfortunate credit. It costs you that much more every time the ratio of loss runs higher; for the cost must be added on to the cost of the business.

So that wherever we can institute means and methods of co-operation with the contractors who are entitled to the credit we reduce the general level of loss, and just so far are we able to reduce the costs of operation for the whole regime.

**The Filing of Credit Statements.**—The contractors, I feel, have had in their minds in years past, the idea we exploited them in working with them; and had a great dislike to the filing of credit statements, that is, carefully analyzed and carefully made credit statements; first, because a great many of them conducted their businesses by themselves, and so forth, and were not well equipped to do it. They felt it was a matter, more or less, of their own private business, and the minute you started to dig into them for a really analyzed credit statement you were treading on a lot of their own personal perquisites. You didn't like to do it. The contractors felt they were successful in building streets, and they came and told us right out. "I have built streets for fifteen years and am here yet. What do you want with a financial statement?"

We get that every day. Now, it is not for me to say whether any of you have that feeling or not; but it is the wrong idea; and the only way to stabilize a man's credit is, not only to know what it is yourself, but to let the other fellow know, so that he can analyze it, too. Because the financial house, the banker or anybody else that you deal with is only anxious that your financial

statement shall disclose a condition which is profitable to you and safe for them, and that they are to help you to make it that way. That is the life of their business, to have everybody be safe all along the line.

The only reason I am talking in this strain, and of the possibilities and the dignity and the real place in the community of the business of manufacturing streets with such emphasis is because I want to drive home that idea, that everybody engaged in it ought to do it right. That is, deal right, from the bottom clear up to the top in their methods, so that there is no question about it, so that the contractor will look himself in the face, and say: "I am not competent to build a \$300,000 job. I am a \$100,000 man. I can make money out of a \$100,000 job; and until I increase my assets I am a \$100,000 man."

**A Good \$100,000 Man and a Poor \$300,000 One.**—There is a good deal more sense and a good deal more of praiseworthiness in a good \$100,000 man than in a poor \$300,000 man, who is taking a contract he is not competent to handle; and if he is financed and if he is bonded it is at the jeopardy of somebody else, because he is not in a condition to handle that piece of work.

Now, the effort is to stabilize these lines of credit with all financial institutions engaged in that line of business, so that the contractor, carrying on a steady line of work year after year, can do the same things that the other manufacturer does with the bank. He goes to his bank and he says, "I am going to manufacture so much. My credits are so much. I shall need one hundred, two hundred, three hundred thousand dollars as a steady line of credit." The bank, taking his condition into consideration, says: "Your line is open to \$200,000; any time you want it during this year." That means, and the banking practice is well settled, that so long as his credit remains in the same condition, his line is open to him; so long as he conforms to the ordinary banking practice he does not have to worry about that, and he goes and gets the money whenever he wants it, because it is his line.

What we are trying to do with the financial houses is to create lines of credit for the men who are in the business of manufacturing the roads and the streets. If your business requires a maximum of so much money during the year, once your line of credit is established it is open to you; so long as you conform to practice you do not have to worry about anything else but your

work. That is the drive which is being made in the line of financing the contractor. It is so that his business can be as much stabilized as any other manufacturing business.

**Difference Between Contracting and Ordinary Manufacturing.**—The question comes, why is it different from other manufacturing businesses; and why must it be handled by specializing houses, with special information and equipment as against banks? In other words, why isn't it an available piece of business in toto for the banks; and why have they not been willing to handle it?

The chief difference between such contractors and the ordinary manufacturing business is that the manufactured product has only one market; that is, the market price is fixed at the time, and it cannot be sold for any other purpose. Secondly, there is no salvage in it. If it is a quarter or a half finished, or three-quarters finished there is no salvage in it as in manufactured or other articles which you can pick up and use for something else. The third is, if the job is not completed in accordance with the contract it has no value which can be picked up and sold to somebody else. It is a failure; it does not conform, and your contract is null. The fourth difference between it and an ordinary manufactured article is that the material which goes into it, by operation of law, carries lien rights, which are superior to the rights of the man who lends you the money. That is not the case in other lines of manufacture. The material man cannot follow his material through a lien into the manufactured article.

In the building of roads and streets, the material man and the laborer can follow his material and labor into the manufactured product, and his lien is superior to the claim of the banker or the man who lends the money on the assessment and credit of the job.

Those are the four divergencies between the road and street manufacturing and the ordinary manufacturing and the ordinary manufacturing business enterprises; and that is why concerns engaged in that business must have a highly specialized force and a highly specialized knowledge of this particular business, and be able to be engineer and follow it through to its completion, in order to keep both the contractor and themselves on a safe basis.

**Ruinous Competition Among the Contractors.**—Let us take up the matter of competition. Under the theory that the bond house, the financial house, is a necessary part of the machinery, you cannot now build roads unless the bonds are sold; and you cannot sell bonds unless they are marketed. We have to market the bonds and to teach the public, and take care of them. We sell bonds and take care of them ten years after they are sold. The street improvement bond is one of the finest securities in the state of California,

but is no good for a large bond buyer, unless there is somebody there to take care of them. They cannot afford to have them, and will not buy them. We have to put the service between the big bond buyer and the details of the street improvement bond in order to sell it, in order to make available security for it; and have to stay there ten years to do it; so the bond house and the contractor have to get together and make these ends possible. That is why your interests are identical on this proposition.

We must all work to the end that the profits of this work can be stabilized at a decent level, not an unusual level; but that level necessary to make a profitable business.

Now I shall show you some figures that seemed rather remarkable and astonishing to me when we got them. These are the figures of the comparative cost of work for the city of Los Angeles. I have no others. I had no other sources of accurate figures available. These are comparisons of costs of work for 1925 and 1926.

Concrete streets in 1925 cost \$43,134 a mile, and in 1926 they cost \$39,586 per mile, which is a decrease of 7 per cent.

Bituminous work (which includes all work, either entirely bituminous surface or concrete base and bituminous top, etc., outside of the patented pavements) cost of 1925 was \$63,130 a mile, and in 1926, \$33,988 a mile; or a decrease of \$29,000 per mile; or 46 per cent decrease in the cost between 1925 and 1926.

In oil roads, those of 1925 cost \$19,159 per mile. In 1926 the cost was \$10,307 per mile; a decrease of 46 per cent.

Going back, by way of explanation, the concrete showed a decrease of 7½ per cent; that is not a correct figure; that is, it does not reflect the correct condition, because—between 1925 and 1926 the average thickness of the concrete road was considerably increased. As nearly as we can get at it by estimates these are the actual figures—it shows a decrease of \$3,000 a mile. The actual cost decrease is probably in excess of 30 per cent, in concrete as well as the other.

What does it come from? The decrease in the cost of material between 1925 and 1926 is probably less than 5 per cent. I think you will all bear me out in that proposition. The actual cost of material—the decrease in the cost of material between 1925 and 1926 is probably less than 5 per cent of the total amount of the job.

Cement, rock, sand and gravel are about 10 per cent down between 1925 and 1926, giving you less than 5 per cent decrease in actual material cost between those periods. Where is the rest of the decrease coming from? It comes from contractors' competitions. It is made up in the losses of contractors, that they have sustained in their work in closer competition.

Now, taking the larger concerns in the state of California which we have been able to contact with, two have stabilized figures and who know exactly what they are doing—they tell us their volume of business (the actual volume of business) shows an increase—between 1925 and 1926—of something between 25 and 50 per cent, varying with the concerns. Their profits, their actual net profits for the year are about 65 per cent of what they were in 1925.

In other words, with an increase of from 25 to 45 per cent in the volume of business, their actual profits for the larger portion are about 65 per cent in money of what they were in 1925.

Now, the only thing which is accountable for that is the internal competition between the contractors—this in a fixed volume of work; there is just so much there.

Here is another thing which bears that out: Mind you, I am holding no brief for the patented pavement; not at all. I simply show you this to prove my point. The cost of patented pavement in 1925 was \$64,196 for the mile. In 1926 it was \$65,971 for the mile; or an increase of \$1,055 per mile.

All right! That means just exactly this: that the prices on that proposition were controlled, and that the competition was shut out of it. As I say, I hold no brief for the patented pavement. That has nothing to do with the argument at all. That is simply one thing to prove the point that I am making; that the cost of building roads today has decreased the amount shown simply through the competition of the contractors—one with the other—in selling a product. You all have the right to sell the product and you have reduced the cost price that much through competition with yourselves in selling a product wherein the buyer had nothing to do or say about fixing the price of it.

**The Contractor Is Entitled to a Fair Profit.**—Now then, when and where does most of the competition come from? Most of the unpleasant competition comes from bidders who are ill-advised about what they are doing. All of you, once in a while, have a reason for bidding on a job cheap. You may be out of work, or something of that kind. The biggest of them is through the contractor who is ill advised, and who does not know what he is doing; or is a breaking-in proposition.

What the financial houses would like to do with the contractors in California who are operating, is to have them understand they are to work together so we can help, with your help (if you will do it) to eliminate from the field of the work the irresponsible bidder, who is ill advised on his contract, and to keep the new man out of the country who wants to come in.

**Elements Controlling Business of Paving Contractor.**—There are four technical elements which control the business of the street contractor: the

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contractor, the surety company, the bond house, and the material man. Those are the four elements which should work together for the handling of this business; and it all comes back to a matter of financing all the time.

As I said in the first place, the contractor is as big as his credit. If he takes advantage of the 10 per cent discount for rock, sand and gravel, it means that he has to borrow that much more money to do it. If he is borrowing the money that cleans that up. We are willing, so far as our proposition is concerned, to stabilize the proposed innovation, eliminating from the materials the credit loss; and the cost of material can be checked by those things going in and making the cost. That is what they are trying to do—trying to push the burden on to the man who loans the money or the contractor who has the money, if he wants to take advantage of that 10 per cent discount.

That is a move along the right way; and that is why I include the material man in the picture. He is the man who has something to say to the new contractor; he has something to say to the irresponsible contractor—whether he can get his credit or not.

The surety man on the other hand has a lot to say to you and everybody else. If you have your lines established, your credits are up, they are taken care of, and are placed in the niche you belong, as a \$200,000 man or a \$300,000 man; or whatever it is; and we have it reduced to something like the regime on which other businesses work. It is a lot worth thinking about, taking the whole thing together—the kind of business it is, the character that it should assume in the community, as one of the big things which has to be done, which adds to the value of the state; and then your methods of doing or your financial methods, business methods—everything of that sort—so it can be stabilized, so banks and other people engaged in a line of business can have a standard on which to operate—so the minute you walk in the door and say, "I have a contract and can handle it this way," that is that. That is a standardized business, business you can meet, and, if you must vary from it, incur your obligations in an ideal situation.

## More Than 22,000,000 Motor Vehicles Registered in 1926

More than twenty-two million motor vehicles were registered in the United States during 1926 according to reports received from state registration agencies by the Bureau of Public Roads of the United States Department of Agriculture. The year's registration represents an increase of 10.3 per cent or slightly more than 2,000,000 more than that of 1925.

Florida with an increase of 40.2 per cent, not including non-resident regis-

trations, shows a greater gain than any other state. Oklahoma, with a gain of 17.8 per cent, and second only to Florida in respect to the amount of increase, was followed closely by Alabama, Idaho, Louisiana, Mississippi and Utah, all of which had increases over 15 per cent.

Of the total number of vehicles registered, 19,237,171 were passenger automobiles, taxis and buses and 2,764,222 were motor trucks and road tractors. The increase in motor trucks and road tractors amounted to 13.2 per cent, which is somewhat greater than the increase for all classes of motor vehicles, indicating a continuation of the development of commodity transportation by highway.

Receipts from registration fees, licenses, etc., amounted to \$288,282,352 as compared with \$260,619,621 in 1925. Of the gross receipts \$190,406,060 was available for highway construction under the supervision of the state highway departments, \$51,702,184 was allocated to counties for expenditure on local roads and \$25,274,158 was used to finance highway bond issues. The remainder was used for payment of collection costs and miscellaneous purposes.

Details concerning the number of vehicles registered and the revenue derived are given below:

	Total registration	Registration receipts
Alabama	225,930	\$2,889,252
Arizona	73,682	467,795
Arkansas	209,419	3,656,368
California	1,600,475	8,477,233
Colorado	248,613	1,507,379
Connecticut	263,235	6,220,668
Delaware	44,834	775,577
Florida	401,562	6,764,468
Georgia	277,468	3,381,725
Idaho	94,760	1,385,930
Illinois	1,370,503	14,047,208
Indiana	772,326	5,093,176
Iowa	698,998	10,208,416
Kansas	491,276	4,603,130
Kentucky	281,557	4,131,745
Louisiana	239,500	3,993,466
Maine	151,486	2,355,365
Maryland	252,852	2,928,268
Massachusetts	690,190	13,077,857
Michigan	1,118,785	16,953,685
Minnesota	630,285	9,976,560
Mississippi	205,200	1,973,412
Missouri	654,554	7,903,025
Montana	103,958	1,029,383
Nebraska	366,773	3,636,097
Nevada	24,014	209,920
New Hampshire	89,001	1,710,905
New Jersey	651,415	11,370,529
New Mexico	54,996	513,743
New York	1,815,434	28,786,421
North Carolina	*385,047	**9,400,000
North Dakota	157,822	1,578,081
Ohio	1,480,246	9,818,873
Oklahoma	499,938	5,515,045
Oregon	233,568	6,017,759
Pennsylvania	1,455,184	24,045,349
Rhode Island	110,746	1,962,898
South Carolina	181,189	1,951,559
South Dakota	168,280	2,429,180
Tennessee	279,639	3,591,296
Texas	1,049,869	14,362,883
Utah	85,380	634,048
Vermont	74,063	1,696,532
Virginia	322,614	4,624,475
Washington	363,279	6,056,003
West Virginia	227,836	3,728,935
Wisconsin	662,282	9,074,490
Wyoming	49,883	499,878
District of Columbia	111,497	566,812
Total	22,001,393	\$288,282,352

\*Estimated for last six months of calendar year, as registration begins on July 1.

\*\*Conservative estimate, as data was not available.

## Some Fast Paving Crews

Although the 1927 road paving season has only just about gotten into its full stride three outstanding high speed paving records have already been established.

One of the fastest records to date was established on June 2 at Thomasville, Ga., when a crew of the Wesco Construction Co. of Chattanooga, working on a 9-hour day, put down a total of 3,832 sq. yds. of 4-in. concrete base with a single 27-E MultiFoote Paver. Converted into terms of standard 18-ft. highway 6 in. thick this is building road at the rate of 141 ft. per hour or 2.35 ft. per minute.

Another remarkable record in which a single crew with a 27-E MultiFoote built 1,515 ft. of standard Bates type 20-ft. pavement between sunrise and sunset was established on May 14 on the LaPorte Highway out of Houston, Texas, when a crew of the Tibbetts Construction Co. kept at it steadily for 14 hours and 15 minutes. The pavement laid was 20 ft. wide and 6 in. thick. Translated into terms of standard 18 ft. highway 6 in. thick this would be building standard pavement at the rate of 128 ft. per hour or 2.13 ft. per minute.

This crew has been consistently building pavement at a high rate, having built more than 1,300 ft. per day four times within a month.

Another job on which a very consistent record of fast work has been made is that of the Dorsey Construction Co. of Findlay, O., on the super-highway being constructed out of Cleveland. This highway is 36 ft. wide and is being paved with an 11-in. slab which is laid half at a time. Using a single 27-E MultiFoote this crew has been consistently building more than 500 ft. of 18-ft. slab, 11 in. thick, per day. Their contract calls for 8 miles of 36-ft. pavement and they expect to complete the entire contract this season with the single paver.

## Highway Bridge Location Discussed in Department of Agriculture Bulletin

The various factors which influence the selection of locations for highway bridges are discussed in Department Bulletin 1486-D, Highway Bridge Location, by C. B. McCullough, Bridge Engineer, Oregon State Highway Commission, and issued by the Bureau of Public Roads, United States Department of Agriculture.

The bulletin discusses the location of minor bridge structures, cost considerations involved in the location of large structures, maintenance considerations affecting bridge location, alignment, grade-line treatments, traffic influence on bridge location, and location over navigable waters.

Copies of the bulletin may be obtained, as long as the supply lasts, by writing to the United States Department of Agriculture, Washington, D. C.

# The Design of a Water-Cement-Ratio Concrete Mixture

A New Method for Designing Water-Cement-Ratio Concrete Mixtures That Is Not Based on the "Fineness Modulus" Theory

By R. P. V. MARQUARDSEN

Assistant Engineer, Chicago Terminal Improvement, Illinois Central Railroad Company

The first issue of Bulletin No. 1 of the Structural Research Laboratory of Lewis Institute, Chicago, entitled "Design of Concrete Mixtures," by Prof. Duff A. Abrams, was published in 1918.

The writer at that time secured a copy of the pamphlet, casually read it, carefully filed it away, and promptly forgot all about it. From time to time thereafter, articles appeared in various engineering publications, relative to some such subject as "Water-Cement-Ratio Concrete," "Water Control in Concrete Mixtures," etc. Articles of this kind always gave the writer a sort of uneasy, if not guilty, feeling. The thought that "perhaps you ought to investigate this new-fangled theory, after all" continually suggested itself, but the counter-thought of "what's the use, it is nothing but a passing fancy" always succeeded in dismissing the matter.

With the adoption, in March, 1927, by the A. R. E. A., of "Specifications for Concrete, Plain and Reinforced" based on the water-cement-ratio theory, the suggestion of "get busy and investigate the matter thoroughly; you will have to do it sooner or later, anyhow" came more forcibly than ever, and so out came old Bulletin No. 1.

**Some Facts.**—The result of a thorough study of this bulletin, and of the pamphlet issued by the Portland Cement Association entitled "Design and Control of Concrete Mixtures," was that the writer became convinced of the following facts (which facts, of course, are not new to those that already have investigated the matter):

A—Other conditions being equal (such as time of mixing, manner of curing, etc.), the strength of concrete depends solely upon the ratio of water to cement, provided the mixture is workable and the aggregates are structurally sound.

B—The grading of the aggregates and the ratio of coarse to fine aggregate is unimportant (except as a matter of economy), provided that the resulting mixture is not harsh and does not produce honey-combed concrete.

These studies, however (together with certain tests made afterwards), also convinced the writer that

C—The "Fineness Modulus" is not a reliable factor for determining the water required to produce a desired plasticity.

D—The ratio of fine to coarse aggregate

established by the limits of the fineness modulus that are given for the several sizes of coarse aggregate is too arbitrary.

**Fineness Modulus Chart.**—To grasp better the significance of the theory advanced in Bulletin No. 1, a diagram, based on formula 4 (with the  $+a-c$  quantity omitted and taken into account some other way), was prepared. This diagram is reproduced as Fig. 1 of this article. It is, unfortunately, not of much practical value, inasmuch as the water requirements are based on formula 4 of Bulletin No. 1, and consequently on the "Fineness Modulus," which as stated above is, in the writer's opinion, not a reliable factor for determining the quantity of water required.

**Checked Up.**—Several designs of concrete mixtures, based on the information represented by the diagram and given in Bulletin No. 1, were carefully made in a laboratory but the results obtained were rather unsatisfactory. In all cases, the actual slump obtained was never near the slump for which the design was made. In one case, the mixture was designed for a 6 to 7 inch slump and the actual slump obtained was zero, leaving the concrete stand, as one of the experimenters remarked, "like a Washington Monument."

To cut a long story short, the writer believes that the method of designing concrete mixtures by means of the "Fineness Modulus" is too unreliable (as well as too unnecessarily complicated) to be of any real practical value.

**A New Method.**—No one, however, should criticise (too severely, at least) any existing method, unless he is prepared to offer suggestions for a new method which he believes (rightly or wrongly) to be an improvement over the old one.

The writer, therefore, in pointing out what, in his opinion, constitutes the shortcomings of the fineness modulus method of designing concrete mixtures, wishes to propose a new method for designing water-cement-ratio concrete mixtures, which he believes will prove more certain of desired results and more practical in application.

**The Theory.**—The several "ingredients" of the proposed method are not new. All of them, in fact, are borrowed from old and new methods. Briefly stated, the theory underlying the proposed method is as follows:

1. The ratio of fine aggregate to

coarse aggregate should be determined by the voids in the loose coarse aggregate.

2. The "initial" (and minimum) ratio of paste to fine aggregate should be determined by the voids in the fine aggregate; and the "final" ratio of paste to fine aggregate, by trial, by adding small quantities of paste (water and cement in the required water-cement ratio) to the "initial" trial batch of concrete, until the required workability is obtained.

3. The ratio of water to cement, given by the specifications, should, of course, be governed by the strength concrete required.

**Nomenclature.**—In discussing the method and developing the necessary formulas, the following nomenclature will be used:

Br = bulking ratio of coarse aggregate, by volume = volume of loose field aggregate divided by loose volume of the same aggregate after drying. May be considered equal to unity.

Bs = bulking ratio of fine aggregate, by volume = volume of loose field aggregate divided by loose volume of the same aggregate after drying.

B'r = bulking ratio of coarse aggregate, by weight = weight of field aggregate divided by weight of the same aggregate after drying.

B's = bulking ratio of fine aggregate, by weight = weight of field aggregate divided by weight of the same aggregate after drying.

C = quantity of cement, by volume. 94 lb. assumed equal to one cubic foot.

Ca = quantity of cement (by volume) added to the initial-mix trial batch of concrete, in order to obtain the desired workability.

C' = quantity of cement, by weight.

C'a = quantity of cement (by weight) added to the initial-mix trial batch of concrete, in order to obtain the desired workability.

Ir = ratio of assumed increase in volume of voids of loose coarse aggregate to actual volume of voids. A value of 0.25 is suggested.

Is = ratio of assumed increase in volume of loose dry fine aggregate to actual volume of voids. A value of 0.25 is suggested for the "initial" mix.

M = Mix in general, by volume.

Mf = "Final" Mix, by volume.

Mi = "Initial" Mix in general, by volume.

Mid = "Initial" Mix, by volume, based on loose dry aggregates.

Mif = "Initial" Mix, by volume, based on loose field aggregates.

M' = Mix in general, by weight.

M'f = "Final" mix, by weight.

M'i = "Initial" mix in general, by weight.

M'id = "Initial" mix, by weight, based on dry aggregates.

M'if = "Initial" mix, by weight, based on field aggregates.

P = quantity of paste (water and cement mixed), by volume.

Pa = quantity of paste (by volume) added to the initial-mix trial batch of concrete, in order to obtain the desired workability.

P' = quantity of paste, by weight.

P'a = quantity of paste (by weight) added to the initial-mix trial batch of concrete, in order to obtain the desired workability.

P'u = unit weight of paste.

R = quantity of dry coarse aggregate, by loose volume.

Ri = quantity of coarse aggregate (by loose volume) in the "initial" mix.

R' = quantity of dry coarse aggregate, by weight.

Ratio of Volume of Water to Volume of Cement

Fig. 1. —  
Structur

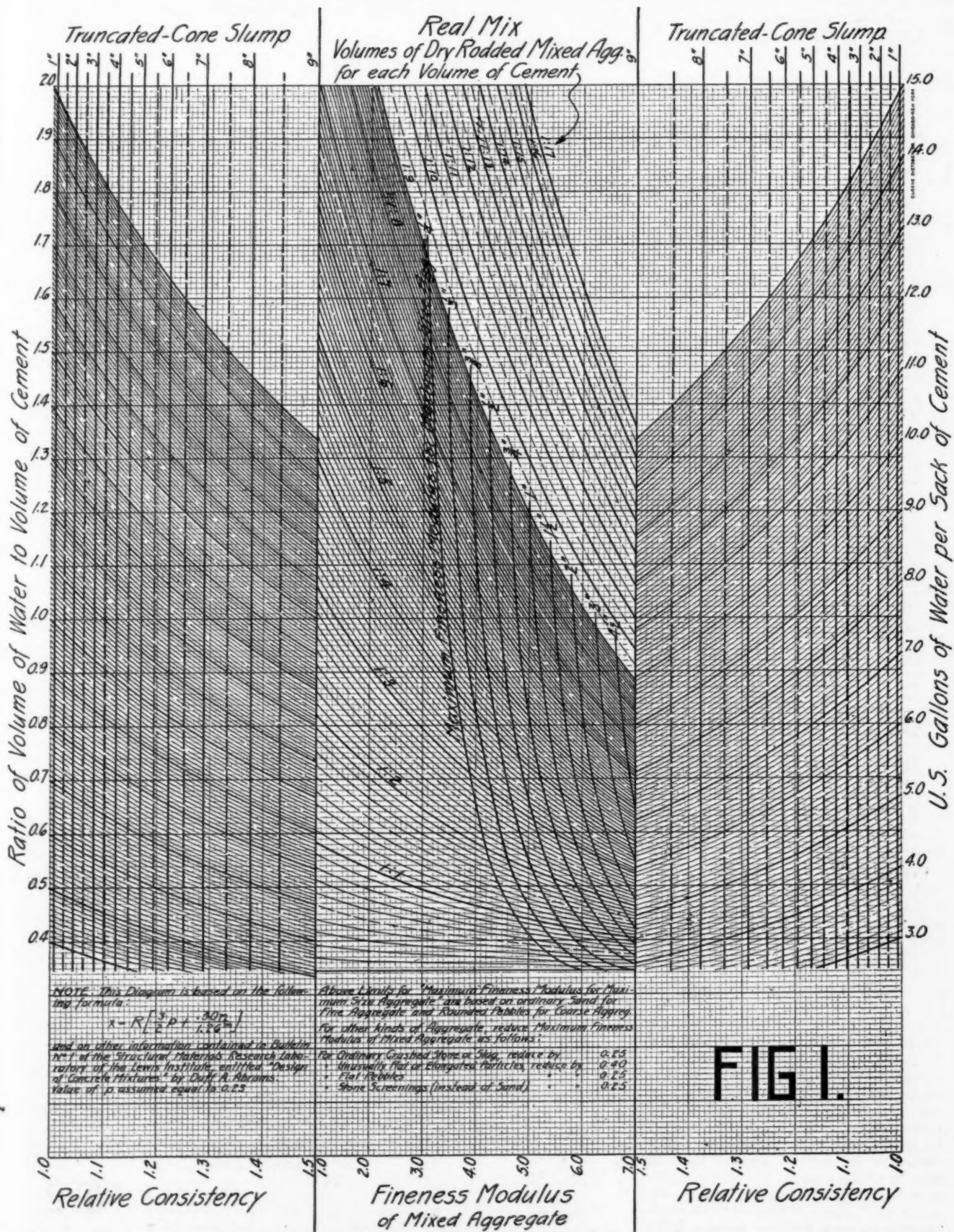


Fig. 1.—Proportioning Chart Based on the Water Requirements as Determined by Fineness-Modulus, Derived from Data Given in Bulletin No. 1, Structural Materials Research Laboratory, Upon Which the Usual Water-Cement Ratio Proportioning Methods Are Founded. The Author Does Not Believe Mixes May Be Reliably Proportioned by Their Data, and Proposes a New Method Explained in This Article

R'l = quantity of coarse aggregate (by weight) in the "initial" mix.  
 R'u = unit weight of loose dry coarse aggregate.  
 S = quantity of dry fine aggregate by loose volume.  
 Sl = quantity of fine aggregate (by loose volume) in the "initial" mix.  
 S' = quantity of dry fine aggregate by weight.  
 S'l = quantity of fine aggregate (by weight) in the "initial" mix.  
 S'u = unit weight of loose dry fine aggregate.  
 Vr = volume of voids in loose coarse aggregate per unit volume of loose coarse aggregate.  
 Vs = volume of voids in loose fine aggregate per unit volume of loose fine aggregate.  
 W = quantity of water, by volume.  
 War = quantity of water (by volume) absorbed by total quantity of coarse aggregate (if dried) used in the initial-mix trial batch of concrete.  
 Was = quantity of water (by volume) absorbed by total quantity of fine aggregate (if dried) used in the initial-mix trial batch of concrete.  
 Wf = total water (by volume) to be added (per sack of cement) to the materials (whether in dry or field condition) used in concrete of the final-mix proportions.  
 Wi = quantity of water, by volume, (per sack of cement) in the "initial" mix, whether based on dry or field aggregates.  
 Wid = quantity of water, by volume, (per sack of cement) in the "initial" mix based on loose dry aggregates.  
 Wif = quantity of water, by volume (per sack of cement) in the "initial" mix based on loose field aggregates.  
 Wtr = quantity of water (by volume) contained in total quantity of coarse aggregate used in the initial-mix trial batch of concrete.  
 Wts = quantity of water (by volume) contained in total quantity of fine aggregate used in the initial-mix trial batch of concrete.  
 W' = quantity of water, by weight.  
 W'ar = quantity of water (by weight) absorbed by total quantity of coarse aggregate (if dried) used in the initial-mix trial batch of concrete.  
 W'as = quantity of water (by weight) absorbed by total quantity of fine aggregate (if dried) used in the initial-mix trial batch of concrete.  
 W'f = total water (by weight) to be added (per unit weight of cement) to the materials (whether in dry or field condition) used in concrete of the final-mix proportions.  
 W'i = quantity of water, by weight, (per unit weight of cement) in the "initial" mix, whether based on dry or field aggregates.  
 W'id = quantity of water, by weight, (per unit weight of cement) in the "initial" mix based on dry aggregates.  
 W'if = quantity of water, by weight, (per unit weight of cement) in the "initial" mix based on field aggregates.  
 W'tr = quantity of water (by weight) contained in total quantity of coarse aggregate used in the initial-mix trial batch of concrete.  
 W'ts = quantity of water (by weight) contained in total quantity of fine aggregate used in the initial-mix trial batch of concrete.  
 X = ratio of water to cement, by volume.  
 X' = ratio of water to cement, by weight.

**Proportioning for Economy.**—The most economical concrete (as far as the cost of the materials required are concerned, if the difference between the price of coarse aggregate and the price of fine aggregate is not too great) would be one in which the voids in the coarse aggregate are just filled by the fine aggregate; but if this ratio of fine aggregate to coarse aggregate is maintained in practise, the result would very likely be a honey-combed concrete on account of it being impossible to get an absolutely uniform distribution of fine aggregate throughout the mixture. The volume of the fine aggregate required for any given coarse aggregate should, therefore, be slightly greater than the volume of the voids in the coarse aggregate; or, which amounts to the same thing, the volume of the voids should be slightly increased if the volume of the fine aggregate is to be taken equal to the volume of the voids. What such increase should be is open to discussion. The writer suggests a value of 0.25 be

used for the increase ratio until actual experience indicates a more desirable figure.

**Aggregate Formula.**—The formula for the ratio (by volume) of coarse aggregate to fine aggregate (dry loose materials) is, therefore,

$$\frac{R}{S} = \frac{1}{(1 + Ir) Vr} \quad (1)$$

For similar reasons it would be necessary to increase the quantity of paste (over the voids in the fine aggregate) by a certain percentage. The percentage that is actually necessary can best be found by trial, as hereinafter explained. For the "initial" (and minimum) quantity of paste, a value of 0.25 is suggested for the increase ratio of the fine-aggregate voids.

**Paste Formula.**—The ratio, by volume, of the loose fine dry aggregate to the "initial" paste may, therefore, be expressed by the following formula:

$$\frac{S}{P} = \frac{1}{(1 + Is) Vs} \quad (2)$$

The volume of paste produced by mixing water and cement is equal to the absolute volume of the cement plus the volume of the water, provided the ratio of water to cement is such that all of the voids in the cement are filled. Assuming that the specific gravity of cement is 3.1 and the absolute volume of a cubic foot of cement is 0.49, the ratio of paste to cement (by volume) is, for the "initial" mix,

$$\frac{P}{C} = 0.49 + X \quad (3)$$

for  $X = 0.51$  (or greater), or about 4 gallons (or more) of water per sack of cement.

Likewise, the ratio of paste to water (by volume) is, for the "initial" mix,

$$\frac{P}{W} = \frac{0.49 + X}{X} \quad (4)$$

**Other Ratios.**—Using the foregoing formulas, the following additional ratios can be established readily:

$$\frac{S}{C} = \frac{P}{C} \times \frac{S}{P} = \frac{0.49 + X}{(1 + Is) Vs} \quad (5)$$

$$\frac{R}{C} = \frac{S}{C} \times \frac{R}{S} = \frac{0.49 + X}{(1 + Is) Vs (1 + Ir) Vr} \quad (6)$$

**Initial Mix.**—Having established the foregoing ratios, and the mix, in general expressed by volumes, being

$$M = C : S : R = 1 : \frac{S}{C} : \frac{R}{C} \quad (7)$$

we find, by using the values given by formulas 5 and 6, that the "initial" mix, by volume, is, based on loose dried aggregates,

$$\text{Mid} = 1 : \frac{0.49 + X}{(1 + Is) Vs} : \frac{0.49 + X}{(1 + Is) Vs (1 + Ir) Vr} \quad (8)$$

and, based on loose field aggregates,

$$\text{Mif} = 1 : \frac{(0.49 + X) Bs}{(1 + Is) Vs} : \frac{(0.49 + X) Br}{(1 + Is) Vs (1 + Ir) Vr} \quad (9)$$

Using a value of 0.25 for  $Is$  and for  $Ir$  and assuming  $Br$  equal to unity,

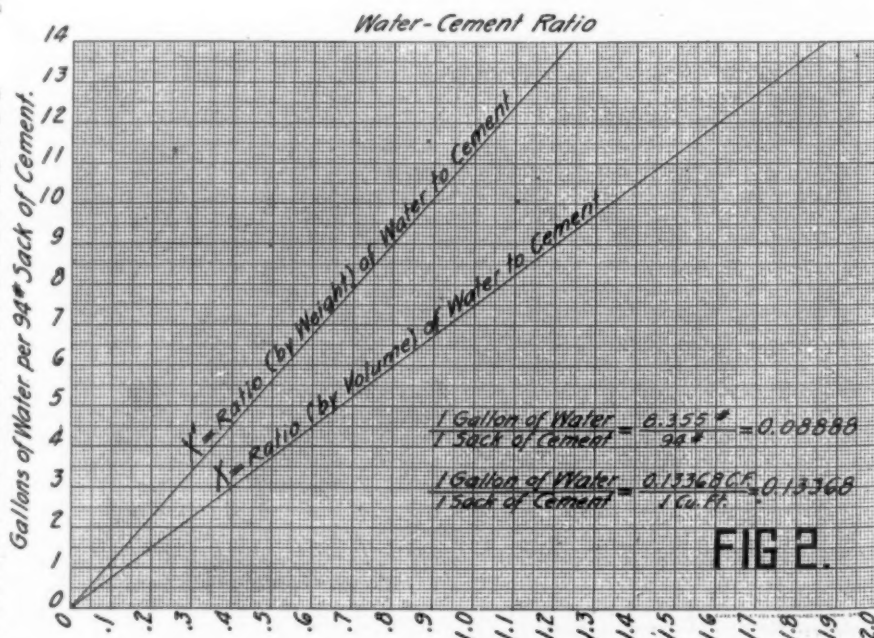


Fig. 2.—Shows Graphically the Relationship Existing Between the Water-Cement Ratio by Weight, the Water-Cement Ratio by Volume, and the Number of Gallons of Water Per Sack of Cement

formulas 8 and 9 become, respectively,

$$\text{Mid} = 1 : \frac{0.49 + X}{1.25 \text{ Vs}} : \frac{0.49 + X}{1.56 \text{ Vs Vr}} \quad (10)$$

and

$$\text{Mif} = 1 : \frac{(0.49 + X) \text{ Bs}}{1.25 \text{ Vs}} : \frac{0.49 + X}{1.56 \text{ Vs Vr}} \quad (11)$$

**Mixing Water.**—The total quantity of water to be added to the "initial" mix (per sack of cement), based on loose dried aggregates (formulas 8 and 10), is X cubic feet plus the quantity of water that will be absorbed by the aggregates, or

$$\text{Wid} = X + (\text{Was} + \text{War}) \quad (12)$$

The total quantity of water to be added to the "initial" mix (per sack of cement), based on loose field aggregates (formulas 9 and 11), is X cubic feet, plus the quantity of water that would be absorbed by the aggregates had they been dried before mixing, minus the total water actually contained in the aggregates, or

$$\text{Wif} = X + (\text{Was} + \text{War}) - (\text{Wts} + \text{Wtr}) \quad (13)$$

**Additional Paste.**—By using the initial-mix proportions given by formula 8, 9, 10 or 11, in mixing a trial batch of concrete, it probably will be found that the mixture is too dry for the workability desired. Small quantities of paste of the proper water-cement ratio will therefore have to be added to the batch until the desired workability is obtained.

Knowing the volume of the total paste added after the initial-mix trial batch has been mixed, the corresponding total cement added may be found by the following formula:

$$\text{Ca} = \frac{\text{Pa}}{0.49 + X} \quad (14)$$

**Final Mix.**—Expressing the "initial" mix, whether based on dried or field aggregates, by

$$\text{Mi} = 1 : \text{Si} : \text{Ri} \quad (15)$$

the "final" mix will be

$$\text{Mf} = 1 : \frac{\text{Si}}{1 + \text{Ca}} : \frac{\text{Ri}}{1 + \text{Ca}} \quad (16)$$

Expressing the total volume of water added to the materials (whether in dried or field condition) used in mixing the initial-mix trial batch by Wi, and knowing that the water added to the trial batch afterwards (in order to obtain the desired workability) is equal to XCa, the total quantity of water to be added to subsequent batches of concrete of the proportions given by formula 16 will be

$$\text{Wf} = \frac{\text{Wi} + \text{XCa}}{1 + \text{Ca}} \quad (17)$$

The foregoing formulas are based on volumes, which is the customary method of measuring materials used in producing concrete.

**Weight Method.**—In the writer's opinion, it would be far more accurate, and far easier to control the water-cement ratio, if all the ingredients of the concrete were weighed instead of determined by volumes.

The variation in weight, for instance, of a certain quantity of sand would probably not be more than 2 to 3 per cent for different field conditions (moisture contents), whereas the variation in volume might be 20 to 30 per cent.

Furthermore, if the ingredients were determined by weight instead of by loose volumes the contractor would be enabled to utilize the full capacity of his mixer, which is not always possible if one or more full bags of cement have to be used per batch of concrete.

For these reasons it is hoped that the day will come when it will be customary to weigh all of the materials (including the water) that go into a concrete mixture.

**Weight Formulas.**—Formulas, similar to the foregoing but based on weights instead of on volumes, can readily be established.

They are as follows:

$$\frac{\text{R}'}{\text{S}'} = \frac{\text{R}'\text{u}}{(1 + \text{Ir}) \text{ Vr S}'\text{u}} \quad (1a)$$

$$\frac{\text{P}'}{\text{P}'} = \frac{(1 + \text{Is}) \text{ Vs P}'\text{u}}{\text{P}'\text{u}} \quad (2a)$$

$$\frac{\text{C}'}{\text{P}'} = 1 + \text{X}' \quad (3a)$$

$$\frac{\text{C}'}{\text{P}'} = \frac{1 + \text{X}'}{\text{X}'} \quad (4a)$$

$$\frac{\text{W}'}{\text{S}'} = \frac{\text{X}'}{\text{P}'} = \frac{(1 + \text{X}') \text{ S}'\text{u}}{(1 + \text{Is}) \text{ Vs P}'\text{u}} \quad (5a)$$

$$\frac{\text{R}'}{\text{C}'} = \frac{\text{R}'}{\text{S}'} = \frac{(1 + \text{X}') \text{ R}'\text{u}}{(1 + \text{Is}) \text{ Vs (1 + Ir) Vr P}'\text{u}} \quad (6a)$$

$$\text{M}' = \text{C}' : \text{S}' : \text{R}' = 1 : \frac{\text{S}'}{\text{C}'} : \frac{\text{R}'}{\text{C}'} \quad (7a)$$

$$\text{M}'\text{id} = 1 : \frac{(1 + \text{X}') \text{ S}'\text{u}}{(1 + \text{Is}) \text{ Vs P}'\text{u}} : \frac{(1 + \text{X}') \text{ R}'\text{u}}{(1 + \text{Is}) \text{ Vs P}'\text{u}} \quad (8a)$$

$$\text{M}'\text{if} = 1 : \frac{(1 + \text{X}') \text{ S}'\text{u}}{(1 + \text{Is}) \text{ Vs P}'\text{u}} : \frac{(1 + \text{X}') \text{ R}'\text{u}}{(1 + \text{Is}) \text{ Vs P}'\text{u}} \quad (9a)$$

$$\text{M}'\text{if} = 1 : \frac{(1 + \text{X}') \text{ S}'\text{u}}{(1 + \text{Is}) \text{ Vs P}'\text{u}} : \frac{(1 + \text{X}') \text{ R}'\text{u}}{(1 + \text{Is}) \text{ Vs P}'\text{u}} \quad (10a)$$

$$\text{M}'\text{if} = 1 : \frac{(1 + \text{X}') \text{ S}'\text{u}}{(1 + \text{Is}) \text{ Vs P}'\text{u}} : \frac{(1 + \text{X}') \text{ R}'\text{u}}{(1 + \text{Is}) \text{ Vs P}'\text{u}} \quad (10a)$$

$$\text{M}'\text{if} = 1 : \frac{(1 + \text{X}') \text{ S}'\text{u}}{(1 + \text{Is}) \text{ Vs P}'\text{u}} : \frac{(1 + \text{X}') \text{ R}'\text{u}}{(1 + \text{Is}) \text{ Vs P}'\text{u}} \quad (10a)$$

**Bulking Ratio.**—Again using a value of 0.25 for Is and for Ir and noting that in this case the bulking ratio of coarse aggregate can not be assumed equal to unity, formulas 8a and 9a become, respectively

$$\text{M}'\text{id} = 1 : \frac{(1 + \text{X}') \text{ S}'\text{u}}{1.25 \text{ Vs P}'\text{u}} : \frac{(1 + \text{X}') \text{ R}'\text{u}}{1.56 \text{ Vs Vr P}'\text{u}} \quad (10a)$$

and

$$\text{M}'\text{if} = 1 : \frac{(1 + \text{X}') \text{ S}'\text{u B}'\text{s}}{1.25 \text{ Vs P}'\text{u}} : \frac{(1 + \text{X}') \text{ R}'\text{u B}'\text{r}}{1.56 \text{ Vs Vr P}'\text{u}} \quad (11a)$$

Also,

$$\text{W}'\text{id} = \text{X}' + (\text{W}'\text{as} + \text{W}'\text{ar}) \quad (12a)$$

$$\text{W}'\text{if} = \text{X}' + (\text{W}'\text{as} + \text{W}'\text{ar}) - (\text{W}'\text{ts} + \text{W}'\text{tr}) \quad (13a)$$

$$\text{C}'\text{a} = \frac{\text{P}'\text{a}}{1 + \text{X}'} \quad (14a)$$

$$\text{M}'\text{i} = 1 : \text{S}'\text{i} : \text{R}'\text{i} \quad (15a)$$

$$\text{M}'\text{f} = 1 : \frac{\text{S}'\text{i}}{1 + \text{C}'\text{a}} : \frac{\text{R}'\text{i}}{1 + \text{C}'\text{a}} \quad (16a)$$

$$\text{W}'\text{f} = \frac{\text{W}'\text{i} + \text{X}'\text{C}'\text{a}}{1 + \text{C}'\text{a}} \quad (17a)$$

$$\text{W}'\text{f} = \frac{\text{W}'\text{i} + \text{X}'\text{C}'\text{a}}{1 + \text{C}'\text{a}} \quad (17a)$$

The value of P'u in the foregoing formulas may be calculated from either of the following equations:

$$\text{P}'\text{u} = \frac{94 + 62.5\text{X}}{0.49 + \text{X}} \quad (18)$$

$$\text{P}'\text{u} = \frac{94(1 + \text{X}')}{0.49 + 1.5\text{X}'} \quad (18a)$$

**Proportioning Records.**—In designing a concrete mixture, a systematic procedure is very desirable, and for this reason proper forms should be prepared for keeping an adequate record of the information established, such as voids volumes, moisture contents, unit weights, bulking ratios, etc. The subject-matter on the forms should be arranged, as nearly as possible, according to the successive steps to be taken in designing the mixture.

A form for quickly correcting the field mix, and the water to be added to the field mix on account of any variation in the moisture content, should also be prepared. The method of determining the moisture content of the aggregate, to be outlined on the form, should be such that no drying out of the aggregate will be necessary.

**Conclusion.**—The writer does not claim that the foregoing discussion is an exact solution to the problem of designing a water-cement-ratio concrete mixture. The problem is not one to be solved by Algebra entirely. But he does feel certain that the results obtained by using the method suggested will give satisfactory results. At any rate, a zero slump will not be obtained if a 6 to 7 inch slump is wanted. The suggested method should also prove superior to the purely cut-and-try method, where everything is left to one's judgment. Nor will the suggested method involve any more (or at least very little more) "laboratory" work than does the purely cut-and-try method. Both methods, of course, require the determination of the moisture content of the field aggregates, which is the biggest item of the "laboratory work." The determination of the volume of the voids in the coarse aggregate, required by the suggested method, does not have to be very

exact, inasmuch as 25 per cent is added for good measure afterwards; and the volume of the fine-aggregate voids may be estimated without involving any error whatever in the "final" mix, inasmuch as paste is added to the "initial" mix until the desired workability is obtained.

The main thing to bear in mind by the man in the field is that the required water-cement ratio must be maintained in order to get uniform-strength concrete, and that the mixture must not be under-sanded if a honey-combed concrete is to be avoided.

## Surveying Large Land Development

Methods Used on 7,000 Acre Project Described in June Journal, Boston Society of Civil Engineers

By CHARLES B. BREED

Professor of Railway and Highway Engineering, M. I. T.; and Consulting Engineer

Lucerne-in-Maine comprises about 7,000 acres of land and water. The land is almost entirely wooded, the topography generally hilly, several places are very rugged and steep.

**The Provisional Survey.**—Surveying was started on this project the first of September, 1925. Within three months the project was opened for sale with 5,000 lots. In that limited time it was impossible to make a topographic survey to use as a basis for determining the location of roads and the shape of blocks and lots. The method adopted was to make a hasty reconnaissance of the districts which were first to be opened for sale, to make a boundary survey of these districts, to determine the position for the roads largely by eye, and to locate a few of the characteristic features of topography, such as brooks, slightly places, limits of woods, and then make a provisional plan of layout of the district indicating all roads, blocks and lots. All lots contain at least 2,000 sq. ft., and most of them contain exactly that amount. The land was sold in units of 2,000 sq. ft., some purchasers contracting for three units, others for ten or twenty, depending upon the size of the site they desired to buy.

The corporation contracted to furnish a warranty deed of the number of lots purchased, these lots to be located by final survey substantially where the provisional lots lay, and final plan recorded at the registry of deeds.

**The Final Survey.**—This required that the final survey should follow promptly the provisional survey, because some of the owners were anxious to build upon their lots immediately. In some cases they paid for the lots outright, and they naturally wanted their deeds immediately. This meant that the final survey work had to be

rushed, and that it, too, could not be based upon any comprehensive topographic plan, on account of the limited time. The method adopted for the final survey was to lay out as nearly as possible the locations of the roads shown on the provisional plans, and to modify these locations in the field as the final survey progressed, improving the road locations on the provisional plan, but departing from them only to a limited extent. Because of the liability that the final survey would produce blocks containing a less number of lots than the provisional plans did, the engineers also withheld from sale certain key lots of the provisional plans which gave a leeway to the Engineering Department of 50 to 100 ft. in length of blocks and 20 to 40 ft. in width of blocks, which latitude made it possible in most instances to select reasonably good road locations in the final survey.

The final survey was made by running a straight line traverse around each block, locating all angle points and tying them in to spikes in those trees which were located far enough back from the proposed road so that they would not be cut down when the swamping process was carried on. All of the field notes, including the ties, were recorded on working drawings in the field office. These were plotted by draftsmen as a part of their regular work, and the ties were drawn on the same working sheets by the chiefs of party who took them. The party chiefs also checked up the dimensions recorded on the working drawings and computed the closed traverse of each block; closure of 1 in 5,000 was required. Every item of detail shown in the final survey notes was transcribed on to the working drawings. These details included locations of brooks, outcrops of ledge, locations of any unusual growth of trees, the recommended radii or external distances of the curves at the angles in the streets, and all ties.

Sheets in this form were then shipped to Boston by registered mail and photostated. One copy of the photostats was left at Boston, and the original sheets returned to the field office, together with several photostatic copies. The latter were then available for use in the field by any field party which had occasion to work in that district, while the working drawings remained in the field office for lot designs.

**Field Notes Recorded on Working Drawings.**—By this method all of the field notes were recorded in systematic form on the working drawings, which effected many advantages. Some of these are as follows:

(1) The notes of every chief of party are finally placed on the working drawing in such an orderly fashion that anybody can read them and understand them. They are also free from all errors except the usual allowable errors in surveying. Where two or more measurements are taken on the same

line the one adopted appears on the working drawing and the others do not there appear. All data are recorded on the working drawings when the details are fresh in the minds of the party chief who took the notes.

(2) The field notes are not taken into the field; photostats of the working drawings are the only things that are taken into the field, and if lost it is an immaterial matter.

(3) If the chief of party quits the job he cannot embarrass it because all of his work has been placed in this record form.

(4) Because of possibility of fire destroying the field office a photostatic copy of the field notes is kept in Boston. This is an extremely important matter in a project of this sort, because the expense of the survey was considerable, due to the process required by the speed with which the sales progressed.

On the working drawings the final design of lots was made and every lot given the same number that it had on the provisional plan, so that the owner received a deed bearing the same numbers as his contract bore. By careful handling of the numbering we were able to conform to this desirable method with every purchaser. In the design, additional lots developed, and in some cases lots were omitted. Where lots were omitted the so-called "Engineers' Lots" were cancelled from the plans, so that none of the lots actually sold were later omitted from final plans. Where additional lots appeared they were given additional numbers.

The final plans were made on tracing cloth, and blueprints from these tracings were filed at the Registry of Deeds. Photostatic copies of blueprints (giving black lines on white background) were furnished the Sales Offices, the Auditing Department and the Legal Department for sales purposes, recording the contracts and issuing the deeds.

These same black line photostats were used for water-supply studies and for record plans of water-supply construction.

**States Increase Gasoline Tax.**—The legislatures of several states have enacted laws increasing gasoline taxes, the proceeds to be used practically all for highway purposes. The states making these increases are as follows: Colorado, 2 ct. to 3 ct.; Montana, 2 ct. to 3 ct.; New Mexico, 3 ct. to 5 ct.; Arkansas, 4 ct. to 5 ct.; Maryland, 2 ct. to 4 ct.; South Dakota, 3 ct. to 4 ct.; Alabama, 2 ct. to 4 ct.; Delaware, 2 ct. to 3 ct.; Idaho, 3 ct. to 4 ct.; New Hampshire, 2 ct. to 3 ct.; Texas, 1 ct. to 3 ct.; Vermont, 2 ct. to 3 ct.; Wyoming, 2½ ct. to 3 ct.

**Snow Removal in Wisconsin.**—The snow removal program in Wisconsin during the past year took in nearly 1,500 miles of state trunk highways and over 1,000 miles of county roads.

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# How a Michigan County Handles Its Highway Work

Plan and Methods Employed in Kent County, Mich., Described in Paper Presented at 13th Annual Road School, Purdue University

By OTTO S. HESS

Engineer-Manager, Kent County Road Commission, Grand Rapids, Mich.

No doubt, a brief explanation of Kent County's organization and road system plan will be in order preceding a discussion of the more technical features of our work. The county road commission is made up of three members or commissioners who are appointed by the county board of supervisors. These three men hold office for a period of six years, a new appointment being made every second year. The road commission is an administrative board only, which meets one day each week largely for the purpose of establishing and maintaining the general policies to be followed by the balance of the organization. The commission employs a secretary who has charge of all records and accounts, and an engineer-manager who has general charge of all activities falling within the jurisdiction of the county road commission not included in the work handled by the secretary.

These activities may be divided into three general classifications: namely, engineering, maintenance and forestry. Each of these classes of work are directly in charge of an engineer, a maintenance superintendent, and a forester, respectively, with all of them entirely responsible to the engineer-manager.

**The County Road System Plan.**—Before going into the details of these various classifications of work it may be of interest to learn a little about Kent County's road system plan, the types of roads being constructed, and how they are financed. We have three general classifications of roads in the county:

1st—The state trunk line and federal aid roads.

2nd—The county road system: that is, the system of roads which is 100 per cent under the supervision of the county road commission.

3rd—The township roads.

The state trunk line and federal aid roads comprise 150 miles of the total system and is quite largely paved with cement concrete. The county road system makes up about 350 miles, some of which are paved with concrete and the balance are gravel. The township roads total about 1,400 miles, some of which are improved with gravel of various widths and thicknesses and the balance, which amounts to a large percentage of the total mileage, are dirt roads, some graded, and others which are only trails.

Under the present Michigan laws the state trunk line and federal aid roads are being constructed and maintained

entirely at state expense. These roads are of interest to the county road commission, however, inasmuch as the county has been handling the maintenance work for the state as well as a large share of the state's engineering work in the county. The township highways are under the supervision of the various township highway commissioners and do not concern the county road commission except in cases where the township boards and the county road commission co-operate so as to have roads built and maintained by the county road commission in the township at township's expense. The 350 miles of improved highways, which are under the direct supervision of the county road commission, are the ones which are of chief interest to us at this time, and are the only ones which will be extensively considered in this paper.

## How the County Roads Are Financed.

—These county roads have been financed by a direct tax upon the county at large and also by an assessment district plan, whereby the cost of a road is met by an assessment upon a district adjacent to the road, an assessment on the township or townships at large and also a portion on the county at large. The first plan, that of direct taxation on the county at large, is the one which is being followed almost exclusively at the present time. This plan calls for an appropriation from the board of supervisors each year and may be called the "pay as you go" plan. The funds so raised by the county are also supplemented by moneys returned to the county from the state, which the state has received as a weight and license tax on automobiles. We also have a gas tax in Michigan, but the counties do not participate in this revenue. In Kent County the total revenue received each from both the county tax and the automobile money ordinarily amounts to approximately \$700,000. All of the activities of the road commissioners are paid for out of this sum, except such occasional jobs as may be constructed under the assessment district plan previously mentioned.

**Types of County Roads.**—Just a word as to the types of roads which we are constructing. Owing to the abundance of good gravel which we have in Kent County a large mileage of gravel roads have been constructed. For the same reason we have found that cement concrete is an economical type for us to build on roads which receive traffic too heavy for gravel surfaces. The result

is that almost all our entire mileage of roads is made up of concrete and gravel with concrete from 16 to 20 ft. in width on the heavily travelled roads. The 20-ft. concrete roads are now costing us about \$35,000 per mile, and the 16-ft. gravel roads are costing from \$8,000 to \$9,000 per mile. These costs include surveys, plans, engineering and inspection.

**The Engineering Organization.**—Our engineering work consists of the making of surveys, road plans, and the supervision of construction contracts. This work is all in charge of a road and bridge engineer, who is in turn responsible to the engineer-manager. Under the direction of the engineer in charge of this department we have quite a number of draftsmen and field engineers. When construction work opens up in the spring the total number of contracts are divided up among three or four field or project engineers. Each project engineer then has charge of the engineering work on a certain group of roads, usually four or five contracts during the whole construction season. The project engineer does not have time to do a great deal of staking work, but has one or more field parties working under his direction doing the various kinds of staking work, which will be described later. All of the inspectors used on the contracts also work under the direction of the project engineer. About the first of September our program for the next year is finally decided upon and the project engineers through their various field parties are given the task of completing all of the surveys for the ensuing year's work, before they are blocked from further field work by extremely cold weather and heavy snows. By September a large number of the contracts have usually been completed or nearly completed so that the field men are able to handle this survey work in addition to their supervision of construction. By Christmas time we are usually forced to cease work on surveys because of weather conditions, but by this time the survey work will, no doubt, have been completed. All of the project engineers and chiefs of parties are then brought into the office and set to work preparing plans for the roads on which they have just completed the surveys. During the winter we do not attempt to hold over our rodmen, chainmen and inspectors, but we do try to hold all of our project engineers and chiefs of parties. As the plans are completed during the winter the various jobs are

placed under contract and when spring work opens up we again find ourselves with a lot of contracts ready to start and our same field men to go out and take charge of the work. This system of handling our engineering organization has worked out very satisfactorily, with the result that many of our engineers stay with us continuously for five to six years. The plan of having the same men handle a road job from the beginning of the survey to the completion of the work also makes for greater efficiency from our engineers and better quality results, in the final construction of the road.

**The Field Work.**—Road surveys are logically divided into two divisions; namely, preliminary or alignment surveys and final surveys. The preliminary survey usually consists in running a transit line down the middle of the road or over a relocation, as the case may be, at the same time obtaining sufficient topography along the line to cover all of the features which should control the final alignment. This preliminary topography also includes essential bridge and culvert data, soundings in swamps and any other special features which may affect the final location of the road. The notes from this preliminary survey work are then plotted up to convenient scale on detail paper showing the position of the transit line with reference to the old travelled track, if there is one, and the locations of all deflection points. The topography notes showing the location of tree lines, buildings, culverts and bridges, and any other special features are plotted in their proper location with respect to the transit lines. This preliminary plan, which is only a pencil drawing on detail paper, is then taken out on the road and studied on the ground with the idea of so fixing the alignment that the road will have the best possible appearance when completed, as well as giving due consideration to the location of trees, buildings, door yards, etc. The position of the transit line on the ground is marked by a stake at the side every 500 ft. as well as all deflection points. With the information shown on the plan and the transit line marked by stakes on the ground it is comparatively easy to work out a final line which will usually eliminate quite a number of the deflection points, leaving only such deflection points as are necessary to conform to existing conditions on the road. In a rolling or hilly country these deflection points are located, as far as possible, on the tops of hills. In this way deflections can be hidden in a great many cases so that they are not visible to one driving on the road, and as far as the traveler is concerned the road appears to be absolutely straight. This, of course, applies only to so-called straight roads. The same kind of preliminary survey and plan, however, applies to curved roads. It should be borne in mind that on the straight roads

the best results can seldom be obtained by rigidly following section lines and no attempt should be made to follow the section lines unless they happen to be in about the right location with respect to improvements and other existing conditions which would be affected by the alignment of the road. If the final line decided upon calls for construction work to be done outside of the existing right-of-way, then additional right-of-way should be purchased so as to include all of the construction work.

After the alignment of the proposed improvement has been fixed the final survey is then handled in the usual way; that is, by setting line stakes every 100 ft. at a uniform distance from the new center line and then proceeding to establish a line of benches, take topography and cross section levels and obtain a set of special notes covering existing bridges and culverts, soundings, and any other special features which would tend to affect the design of the road. Time will not suffice for an exhaustive explanation at this time of the details of just how all of this is done. It may be truthfully said, however, that surveys cannot be properly made according to a set of rules laid down by someone else, if the chief of party has not had sufficient experience on construction work to know what the essential features of a survey should be and what their relation is to the design of the road.

**The Road Plans.**—When the road plans are drawn up in the office the profile and the topography are inked in right from the start. The proposed grade line, culvert notations and any special features of the work should not be inked in until there has been a field inspection of the plans. At this point the plans are taken in the field and studied carefully with the idea in mind of fixing a final grade line which will properly fit existing conditions on the road and at the same time get a balanced grade as far as it is practicable to do so. At the time this field or grade inspection work is done the engineer who makes the grade inspection notes on the plans, any changes which should be made in the grade line, notes the final sizes, types and locations of culverts and bridges to be adopted, the location of guard rail, driveways, and any other features which go to make up a properly completed road. These plans are then taken back into the office and finally completed.

In all of this survey and plan work the road must be designed so as to have alignment and grades in keeping with the volume of traffic which it is expected the road will be called upon to carry. This may be explained by saying that on light travelled roads one may be less rigid with respect to grades and alignment than on heavily travelled roads. As an economic proposition, the amount of money spent to get certain specified grades and alignment should be somewhat in proportion to the volume of expected traffic.

**Handling Construction.**—After a road is placed under contract there is quite a volume of field engineering work to be accomplished if we want to be sure that we get the proper construction of the road, and in accordance with the plans. As previously explained, the same men who made the plans also have charge of this work for us. We start out by slope staking the road for the rough grading operations. At this time we usually also stake out all culverts and bridges as the contractor progresses with his work. After the rough grade has been constructed we set shoulder stakes every 100 ft. to enable the contractor to do the final trimming up of the grade. As fast as the grade is trimmed up and completed our survey parties check up the grade and cross section it at the same locations at which cross sections were obtained on the survey. By following this work along as the contractor progresses we are able to have men in the office compute the final earthwork quantities, so that when the road is done we are in a position to make final payment to the contractor, and not ask him to wait for a considerable length of time on account of the final computation and determination of quantities. After the grade has been trimmed up and completed it is then trenched with a grader by grading out from the center, leaving a sub-grade which is ready to receive the surface. The shoulder dirt for the final trimming, however, is then on the shoulders where it belongs, and there is practically no longitudinal haul of dirt after the surface has been placed. Up to this point the construction features are essentially the same no matter what type of surface is placed. In the case of a gravel surface, the inspection of the gravel with reference to quality, thickness, etc., is taken care of by the project engineer in charge of the job. In the case of a concrete pavement, however, it is necessary to place inspectors at the mixing plant and the proportioning plant, and on some jobs at other points on the construction. These inspectors work under the direction and supervision of the project engineers. It will not be necessary to explain the details of this inspection work at this time as, no doubt, most of you are familiar with this class of work.

**How Prompt Payment Is Made Contractors.**—As construction work progresses on the various contracts our project engineers obtain the actual quantities of work completed from day to day. By keeping up their notes on this information constantly they have a perpetual inventory at all times of work completed. This enables us to make final payments to the contractors just as soon as the contract has been completed and the work accepted. By making prompt payments in this manner we not only create a more satisfactory feeling among the contractors, but we believe this also has its effect on the contractors' bids.

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**Cost of Engineering Work.**—A little information with reference to the cost of the engineering work just described to you may be of interest. Our completed surveys cost approximately \$200 per mile and the plans \$100 per mile, making a total of approximately \$300 per mile, which completes survey and plans. This cost is much less, however, than the cost of engineering, and supervision of the work during the progress of construction. On our gravel roads the cost of surveys, plans, supervision and inspection amounts to approximately 8 per cent of the amount of the contract. On the paving jobs this figure is approximately 3 per cent.

**Three Classes of Maintenance.**—The subject of maintenance as applied to Kent County may be divided into three kinds or classes of maintenance work; namely, road maintenance, bridge maintenance, and the maintenance of buildings and equipment. The maintenance of our roads and bridges is handled under the direction of a maintenance superintendent, who is aided by four district superintendents. Each district superintendent looks after the roads and bridges in approximately one-quarter of the total area of the county, which by the way, is larger than the average county; having 24 townships instead of 16. Each district maintenance foreman has a garage or headquarters place in his district and all operations of equipment for his district are handled from his headquarters place rather than from the main plant at Grand Rapids. This feature of our maintenance work not only facilitates and speeds up the work, but over the period of a year saves a large amount of money. The maintenance of buildings and equipment is handled by the man known as our plant superintendent, who has his headquarters at the main plant in Grand Rapids and who is directly responsible to the engineer-manager. We will not have sufficient time to go into all of the details of our maintenance work, but will try to bring out the main points sufficiently to show the methods employed in our county. Our road maintenance may be divided into three general classes of work. First, general maintenance or that kind of work which applies to all types of roads. Second, the maintenance of concrete surfaces. Third, gravel surfaces.

**General Maintenance.**—Under the head of general maintenance may be included the repair and painting of guard rails, the repair and rebuilding of culverts, shoulder maintenance, cleaning out ditches, cutting weeds and brush and the maintenance of markers and signs. All of this work is handled under the direct supervision of our district maintenance superintendents. No doubt, all of this work is more or less familiar to most of you and it will not be necessary to go into details. I might state, however, that the painting of guard rails is not done by

hand, but is handled with a spray machine and two men. The spray machine, which includes engine, compressor, paint tank, two lines of hose with spray guns, is mounted on a light truck so that the whole outfit can be easily moved along as the work progresses. One man operates the truck and paints the inside of the guard rail, while the other sprays the outside. It is interesting to note that the standard wooden guard rail can be painted in this manner for about \$0.01½ per foot against \$0.04 and \$0.05 per foot for doing the same work by hand. Of course, the painting of cable guard rails, which we are using almost exclusively at this time, is much less than this.

**Maintenance of Concrete Surfaces.**—The maintenance of concrete surfaces consists mainly in pouring tar on asphalt into the cracks and joints once or twice each year and such concrete patching work as becomes necessary from time to time. The maintenance of cracks and joints is handled by a crew of four or five men equipped with a truck and a tar or asphalt heater mounted on a rubber tire trailer behind the truck. The sand for covering the hot material is carried on the truck as well as the supply of additional tar or asphalt and the other small tools used in the work. Two outfits like this one are required to handle all of this work for us.

Concrete patching work has not yet become a very serious operation with us in Kent County, but we have been forced to handle a small amount of such work. For this purpose we have rigged up a pavement breaker which is simply a large cast iron weight which is raised up and down over a small crane projecting from the rear end of a truck. A hoist mounted on the truck raises the weight and lets it drop onto the concrete to be broken. This works quite satisfactorily and saves considerable time and money in the removal of the old concrete. The replacement of the patch is handled in the same manner as the placing of new concrete on a regular paving job, except that we usually use some method to obtain early strength in the concrete so that the patch may be opened within a short time. In extreme cases where we are forced to open the patch in one day we have used Lumnite cement and a rather rich mix. Due to the high cost of this method, however, most of our patching has been done with the use of a rich mix and the addition of calcium chloride in solution in the mix to obtain the early strength desired. This method enables us to open the road in about three days. This plan of handling patch work has been followed by us for the past two years and up to the present time has given good results.

**Gravel Road Maintenance.**—The maintenance of our gravel roads makes up a larger part of our work than all of the other maintenance features put

together. Briefly, our system on this work consists in keeping a thin layer of fine screened gravel on the surface of the road at all times, and by keeping this thin layer of gravel properly distributed over the surface of the road by the use of motor trucks equipped with spring scrapers. We operate four gravel screening plants of our own and these plants are moved from one gravel pit to another as the work requires. We own a great many gravel pits and by using fairly light portable gravel screens we are able to get out screened gravel reasonably close to the places where the gravel is to be used. We have used nothing but screened gravel all under 1 in. in size for the past five years.

For the scraping work each district is supplied with three or four 3-ton trucks with 10-ft. spring scraper attachments. These scrapers operate at a speed of 8 to 10 miles per hour and handle all of our scraping work except the use of a very heavy grader once or twice a year.

**Dust Prevention.**—One feature of our gravel road maintenance work is followed up more closely in Kent County than in most parts of Michigan is that of laying the dust. During 1926 we used approximately 2,000 tons of calcium chloride on both the county and state trunk line gravel roads. We buy the chloride in 100-lb. sacks during the winter and have it shipped to our several district plants. Here it is stored until we are ready to use it. As soon as the roads begin to get dusty in the spring, which is usually some time in May, we start spreading the chloride on the roads in amounts of approximately ½ lb. of chloride per square yard of gravel surface. The chloride is spread on the road by the use of a truck and a chloride drill or lime sower hooked behind. The chloride is carried on the truck and a couple of men empty the sacks into the drill as they proceed along the road. It is not necessary to stop until the entire load of chloride has been used up, and by that time another truck load will have arrived and the men and drill simply transfer to the other truck, letting the empty one go back for another load.

The quantity of chloride necessary to properly lay the dust for a whole season depends largely on the volume of traffic using the road. We have been following a rule about as follows for the total season's requirements:

1st—No dust layer used on roads getting less than 100 vehicles per day.

2nd—One pound of chloride or two ½-lb. treatments for roads getting from 200 to 500 vehicles per day.

3rd—One and one-half pounds or three treatments on roads getting from 200 to 500 vehicles per day.

4th—Two pounds per square yard or four ½-lb. treatments for all roads which have more than 500 vehicles per day.

In extreme cases where gravel roads receive 3,000 to 4,000 vehicles per day

it is necessary to use another  $\frac{1}{2}$ -lb. treatment of a total of  $2\frac{1}{2}$  lb. per square yard for the season. In Kent County, however, we have a few roads in the last classification, but none in the first; that is, with less than 100 vehicles per day. This plan of distributing dust layer in proportion to the volume of traffic has worked out very satisfactorily for several years. For the benefit of anyone just starting in to use chloride I would caution against the use of too heavy treatments. Too much chloride has a tendency to harden the surface, which makes it difficult to scrape and eventually results in a road which becomes rough and pitted. For the first treatment on roads which have never been treated before I would advise using a treatment not to exceed 1 lb. per square yard and for all future treatments I would recommend the schedule just described to you. The best results can be obtained by the use of many light treatments rather than a few heavy ones.

The cost of this dust layer work amounts to approximately \$30 per ton applied on the road. This makes a dust layer cost of from \$100 to \$300 per mile, depending upon the quantity used. This may seem like a considerable amount of money to pay for simply laying the dust, but as a matter of fact the chloride does much more than lay the dust. We know from past experience that it costs almost the same price to maintain a gravel road without a dust layer of calcium chloride as it does with such a treatment. We can only draw one conclusion from this and that is that the chloride saves a large quantity of gravel by holding the binder on the road. We know that this is true and a study of our cost records show that the chloride saves almost enough gravel to pay the entire cost of the dust layer.

The system of gravel road maintenance which I have just outlined to you has worked out very satisfactorily and economically in Kent County. As proof that our maintenance work is highly satisfactory to the local public we can safely refer you to almost any resident of Kent County and expect him to be a booster. With no spirit of boastfulness whatever, we can truthfully say that our system of maintaining gravel roads produces smoother riding surfaces than the large majority of hard surfaced pavements.

**Bridge Maintenance.**—The maintenance of bridges in Kent County for the past five or six years has consisted chiefly of reflooring and reconditioning old steel truss bridges. In most cases the bridges are inherited from the townships and we find them only 16 ft. wide with greatly loosened and vibrating steel work and worn out transverse plank floors. Of course, we can not widen the roadways on these bridges under any systems of maintenance, but we have been able to place a number of them in a much more satisfactory

condition. This is ordinarily done by taking off the old plank floor, replacing worn out stringers, tightening up and painting all of the steel work and placing a new floor. On this type of work we have found 2x4's placed on edge transverse to the roadway and spiked together so as to cover the entire floor surface to be a very economic and satisfactory floor. By fastening this floor down to the stringer and floor beams with "U" bolts we have been able to eliminate the vibration which a bridge receives from a transverse plank floor. If No. 1 Long Leaf Yellow Pine 2x4's are used for this work the floor will remain in good condition for at least five or six years, and quite often by this time arrangements for financing the construction of a new bridge have been worked out; otherwise the floor can be again replaced for less money than almost any other conceivable type of smooth riding floor.

**Maintenance of Buildings and Equipment.**—The maintenance of buildings and equipment falls under the supervision of our plant superintendent, who looks after everything in connection with our main plant and offices in Grand Rapids, and has complete charge of the repair of all equipment. Only about one-quarter of all our equipment is kept constantly at this plant, but a check-up system has been established whereby every motor vehicle goes to the Grand Rapids plant once each month for a complete check-up and then goes back to its district in first class condition. Sometimes this check-up can be done in a couple of hours and in other cases a complete overhaul is required. At least once each year a new painting job is included. Any minor repairs on the trucks in the three districts outside of Grand Rapids are taken care of by a repair man at the district garage. For major repairs, however, the trucks or other motor vehicles are taken to the Grand Rapids plant.

In addition to this check-up system we employ mechanics to do certain night work on equipment. This work consists chiefly of greasing and oiling, tightening nuts and bolts and other minor repair work. By the employment of a few night men in this way we save the time of a large number of men during the day, and also greatly facilitate the work. This is particularly true of work on cars which are being used during the day by survey parties.

**Forestry.**—By virtue of a recent law in Michigan the board of county road commissioners is also made the board of county park commissioners and are responsible for the care and improvement of all county parks. We have to handle this work together with certain other beautification work along our roads.

The roadside development work consists of trimming the existing trees and shrubs, planting new ones and miscellaneous other work, such as sodding,

stabilizing sand banks by certain planting, etc. The entire county road system has been taken care of in this manner for about five years. It costs approximately \$75 per mile to properly trim the roadside trees and shrubs the first time over but subsequent trimming is handled for approximately \$5 per mile per year. Some planting has been done in the open spaces along our roadsides, but because of the abundance of natural roadside trees and shrubs now in existence the most of our planting work has been confined to our county parks.

Our park system has been in operation only a few years, but has developed into one of the most popular features of all the road commission activities.

**Control of Location of Pole Lines.**—Another phase of our work which is placed under the supervision of our forester is that of controlling the location of new pole lines along the highways and any tree trimming work which is done by any of the pole line companies. These companies are required by law to obtain a permit from the highway authorities before doing any trimming work and consequently the details of this matter left with our forester to work out. This system has forced the pole line companies to employ trained foresters of their own which results in a quality and kind of trimming work done by these companies which was never before realized. By the relocation of pole lines it is also made possible to do away with all trimming on many long stretches of road.

**Bookkeeping and Accounting.**—In conclusion it may be of interest to say just a few words with the reference to the bookkeeping and accounting in all of our work. We have a system of daily reports from truck drivers, foremen, mechanics, etc., so that all work done is properly charged against the road or piece of equipment where it belongs. These daily reports from the various sources are made as simple as possible and are collected and correlated in the main office. The final result is furnished us with a complete and accurate cost on all of our various kinds of work. These cost records are especially valuable in connection with the operation of our motor equipment. We have realized that it is very easy to burden an organization with too much paper work and this idea has been constantly kept in mind in working out a system of reports which are simple and concise, but which nevertheless furnishes all of the information needed for accurate cost records.

**Grade Crossing Elimination in Texas.**—An attempt to require, by law, railroads in the state to eliminate all grade crossings in the state, is being made in the Texas legislature. The State Highway Engineer would be empowered to supervise all such construction.

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# Foundations for Highway Bridges

Relative Advantages of Various Types Discussed in Bulletin U. S. Department of Agriculture

By C. B. McCULLOUGH

Bridge Engineer, Oregon State Highway Commission

Many times the range of choice in the location of a bridge may involve several kinds of foundation conditions. In order to properly balance the various merits of each location, it becomes necessary to know the relative advantages of these various types of foundation conditions. It is impossible to formulate any definite or fixed rules for judging the relative merits of different conditions, these being to a large degree modified by the nature of the individual problem. The following brief discussion of the most frequently encountered foundations may, however, prove enlightening as far as general principles are concerned. This discussion does not apply to deep foundation work employing compressed air or open dredging to great depths, but only to the foundation conditions ordinarily encountered in ordinary highway bridge practice.

—18.0 as shown. The bid price on piling was 40 ct. per lineal foot in place. The total weight of the center pier and superstructure resting thereon was 1,348.75 tons. From elevation —18.0 to elevation —30.0 the soil encountered was a sand-clay mixture with insufficient resistance to afford lateral stability to piling. When the work on the piers was started, it was thought that the soil between elevations —30.0 and —50.0 would be such as to admit the penetration of piling for a sufficient distance to insure adequate lateral support. Figure 2 illustrates the condition expected. Instead of this formation, solid foundation material (cemented gravel) was encountered at elevation —30.0, and owing to the fact that the superimposed load was a moving one, it was considered the part of prudence to redesign the foundation to

one central tube with a 7-ft. diameter give a combined area of

$$\frac{(4.5)^2 \pi}{4} \times 6 = 95.5$$

$$\frac{(7.0)^2 \pi}{4} = 38.4$$

133.9 sq. ft.

The following is the actual cost of the work constructed as indicated in Fig. 3:

Steel tubular caissons in place, 22,980	
lb., at 9 ct.	\$2,068.20
Excavation in tubes, 59.5 cu. yd., at \$6.	357.00
Concrete in tubes, 55.33 cu. yd., at \$25.	1,383.25
Total	\$3,808.45

In other words the encountering of rock or hardpan at elevation —30.0 increased the cost of this work from \$1,224 to \$3,808.45. Of course, if the foundation encountered had been hard rock, a higher unit load on the foundation could have been employed and some saving made thereby. The cost, however, could not have been brought down to the cost of the piling foundation.

Subaqueous rock foundations are grouped in the order of their desirability as follows:

- (1) Exposed rock in still water at shallow depths.
- (2) Rock overlaid with a stiff impermeable cover.



Fig. 1—Railroad Bridge Over Columbia River at Celilo, Ore. This is a Good Example of Site Section Based on Foundation Conditions. Every Pier Is on Exposed Solid Rock, a Condition Not Encountered at Any Other Crossing Within the Zone of Selection

**Type A. Exposed Solid Rock of Satisfactory Quality.**—This is without question the most satisfactory, certain, and cheap foundation condition which can be obtained. Figure 1 shows an example where advantage has been taken of foundations of this character in the bridge location.

**Type B. Subaqueous Solid Rock.**—The idea seems to have gained prevalence, especially among those who have had little actual construction experience, that any solid rock foundation is to be preferred to softer material at the same depth. This, however, is far from true; in fact, for subaqueous work, the presence of solid rock under certain conditions may entail an expense much greater than if a reasonably stiff clay were encountered at the same depth. This point is illustrated by Fig. 2, which is a sketch showing the principal dimensions of the center pier for a 239-ft. steel-draw span, built over the Coquille River under the writer's direction, in 1921.

The original plan contemplated the driving of timber piles below elevation

insure maximum lateral stability. After several tentative redesigns had been prepared, the scheme shown in Fig. 3 was finally adopted as the cheapest possible solution. This method of construction utilized seven steel tubes carried to solid rock and filled with concrete, as shown in Fig. 3. The following is a comparison of cost for the two types of foundation:

Scheme No. 1: (Possible if stiff clay had been encountered at elevation —30.0.) Total weight of structure above elevation —18.0, 1,348.75 tons. Number of piles necessary at 15 tons

per pile,  $\frac{1,348.75}{15} = 90$ . Assuming a

penetration to elevation —50.0, the total quantity of piling needed would be  $90 \times 34 = 3,060$  lin. ft., and at 40 ct. per foot the cost would be \$1,224.

Scheme No. 2: (Possible for soft rock or hardpan at elevation —30.0.) Total area of base needed at 10 tons per square foot unit loads would be 134.8 sq. ft.

Six tubes with 4½-ft. diameter and

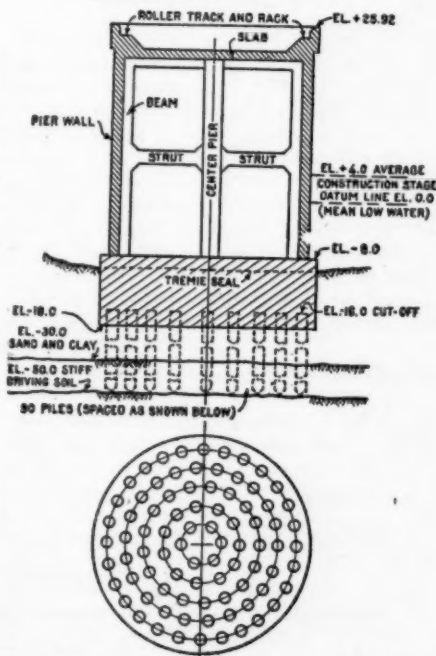


Fig. 2—Details of First Design of Pier for Swing Span Over Coquille River Showing Foundation Conditions Expected

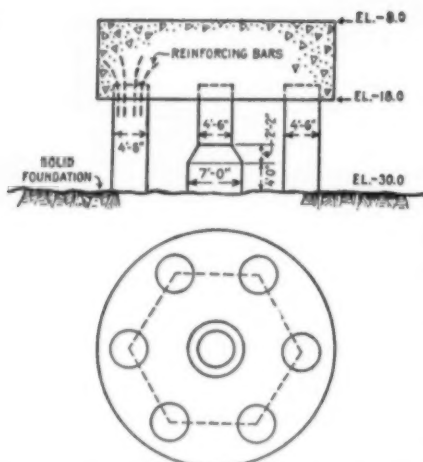


Fig. 3—Redesign of Pier for Swing Span Over Coquille River Necessitated by Encountering Solid Foundation at Elevation -30.0. This Design Covers Considerably More Than the First Design in Which It Was Anticipated That Piles Could Be Driven

- (3) Rock overlaid with a stiff permeable cover.
- (4) Bare rock in still water and comparatively deep.
- (5) Bare rock in swift current water and comparatively deep.

Class 1 admits of the construction of cheap sack dams as shown in Fig. 4. After these are constructed they may be unwatered easily and calked or plastered either from the inside or outside to stop any large leaks. The rock surface can be worked to roughen and to "heel in" the pier base and back forms may be built and easily sealed at the bottom as shown. This type of construction may be used for depths such as can be held by sack dams and in currents which are not too swift to permit working around the sack dam.

Classes 2 and 3 are illustrated in Fig. 5. Where the cover is impermeable, as indicated at the left, the foundation may be kept dry by intermittent pumping from a sump located between the sheet piling or crib and the pier forms and no seal is necessitated at the base. Where the cover is permeable, as shown at the right of Fig. 9, a tremie or bottom-dump bucket seal of thickness sufficient to withstand the hydrostatic head  $h$  must be placed before the dam can be unwatered. This seal must, in general, be of a thickness equal to  $\frac{62.5}{150} h$ , or about  $0.4 h$ . For great depths, the cost of this seal becomes very high and for

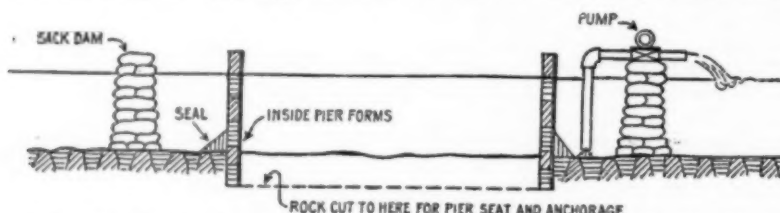


Fig. 4—Sack Dam Used in Foundation Work on Rock at Shallow Depths and Where the Current Is Not Strong

very great depths the use of the pneumatic caisson is more economical.

With classes 4 and 5 where the rock surface is bare, the cofferdam construction becomes more costly. Even with a permeable cover, it is generally possible to get enough sealing effect outside the dam for unwatering for the short time sufficient to inspect the rock surface. For bare rock, however, this can be accomplished only by the construction of a double-walled puddle dam, as shown in Fig. 6, which is very expensive, or by the use of a submarine diving outfit, which is also costly. It is very essential that bare rock foundations be inspected in the dry, if possible, and also that the masonry be well "heeled in"—generally from 8 to 30 in. into the solid rock if the current is swift.

**Type C. Gravel or Boulders at a Reasonable Depth, Where a Penetration of a Few Feet into the Same Is Sufficient to Guard Against Erosion.**—Footings on this material must, in general, be larger than on solid rock; on the other hand the placement of sheeting or cofferdams is many times easier than on solid rock, since it is possible to drive the sheeting into the substrata a sufficient distance to brace it at the bottom.

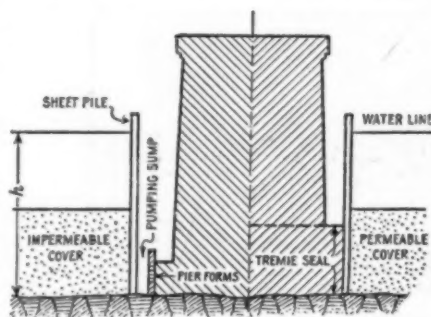


Fig. 5—Methods of Pier Construction Where Rock Is Overlaid by Permeable and Impermeable Cover

**Type D. Material Which Is Soft Enough to Permit the Driving of Piles, Yet Stiff Enough to Afford Lateral Stability.**—This type of foundation requires an area of not less than 2.5 by 2.5 ft., or 6.25 sq. ft. for each pile used. For a 20-ton bearing per pile this is equivalent to that of a natural soil of about 3 tons per square foot bearing capacity. For locations exposed to excessive erosion, this type of foundation affords a greater insurance against scour than does one on a gravel or boulder formation, unless the latter is carried to a depth as low or nearly as low as the bottom of the piling which would in

general result in a much higher first cost than the pile foundation.

**Type E. Very Soft Material of a Considerable Depth Overlaying a Hard and Impenetrable Subsoil.**—This type of foundation precludes the use of piling on account of the lack of lateral stability. Resort must be had to the sinking of individual tubes or piers well heeled into the solid or to the carrying of the entire foundation down to solid material. (Fig. 3.)

**Type F. Boulders of Loose Rock at a Great Depth of Water.**—This is one of the most difficult foundation conditions encountered. Piling can not be driven. Difficulty is almost always encountered in excavating within a crib and in founding a crib in such manner as to make it possible to unwater the cofferdam. On the other hand, it is not the part of prudence to found on such material without a thorough inspection, preferably in the dry, and the removal of all loose material. Where the water is swift, footings must be anchored against lateral movement or sliding along inclined rock or boulder surfaces, and this anchorage can be accomplished best only in the dry.

In weighing the relative merits of the various types of foundation conditions, as above outlined, the following facts should always be borne in mind:

A sheet pile cofferdam is generally cheaper than a crib of like dimensions if it can be used.

For any type of foundation, except piling, the cost increases nearly as the square of the depth below water surface.

Crib work on a pile foundation need not be unwatered, but can be sealed with concrete placed with a tremie or bottom-dump bucket. Footings through semisolid material, such as stiff clay or gravel resting on solid rock overlaid with such material may be similarly placed, since the overburden affords the necessary lateral support. Footings on bare rock or on rock overlaid with soft material must be anchored laterally, for which purpose it is generally necessary to excavate into the rock a short distance. For this reason, and also to avoid the danger of founding upon inclined rock surfaces or large loose boulders, it is generally necessary to unwater foundations of this kinds.

For relatively great depths, the cost of a concrete seal of sufficient thickness to resist the hydrostatic head during

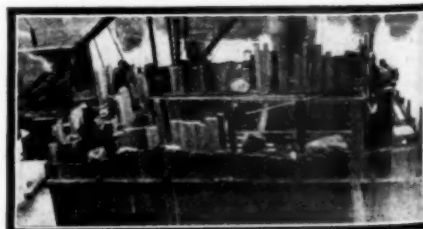


Fig. 6—Double Wall Puddle Dam Construction on Oregon City Bridge. This Type of Construction Was Made Necessary by Solid Rock Foundation Without Overburden and at Too Great a Depth to Permit the Use of a Simple Sack Dam

construction is a large item. Considerable saving may then accrue if an impermeable or nearly impermeable material is encountered, as in this case the water surface surrounding the cofferdam may be kept lowered by means of a double wall dam or an auxiliary pumping pit, until the concrete in the footing base has been placed.

In making a bridge reconnaissance, the engineer should bear in mind that exposed rock at the water's edge, even if both banks of the stream disclose the same formation, does not always indicate a rock bottom extending across the channel. There are numerous instances where a stream during a former geologic period has cut a deep gorge which during a subsequent period has been filled with a lava flow or with glacial, or alluvial débris. The Hudson River is a classic example of this action. Here the river gorge has been filled to a depth of a thousand feet due to a general land subsidence which converted the lower reaches of the river

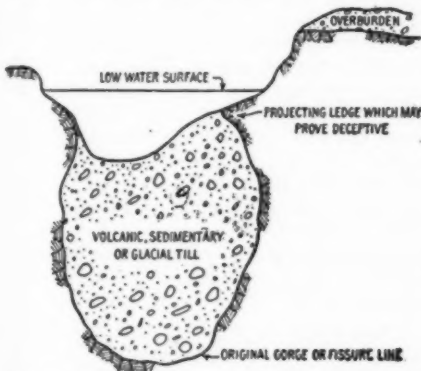


Fig. 7—A Buried Channel or Fissure Formation

into an estuary or bay in the comparatively still water, of which a general sedimentation occurred. A later re-elevation of the land reconverted the bay into a river and the flow during the present period is through and over the sedimentary deposit which overlies the original gorge floor for a depth of a thousand feet or more. In certain areas in the West, deep rockbound gorges have been partially filled through subsequent lava flows and in the glaciated sections glacial gravels or glacial till is found filling up old buried channels in the original rock formation.

In certain instances river gorges have had their origin in a fissure formation or in the comparatively rapid erosion of intrusive dikes of material softer than the surrounding rock.

In view of the foregoing, a condition as indicated in Fig. 10 may quite possibly be encountered. In such a case, it might easily be possible to mistake the overhanging edge of the buried channel for solid rock bottom, and to form the conclusion that this formation extended clear across the stream. A careful investigation of the general characteristics of the river gorge should be made before judgment is passed upon foundation conditions.

Conditions as shown in Fig. 7 are apt to be encountered:

Where a river gorge has become sedimented due to land subsidence or other geologic action converting streams into lakes or bays.

Where lava flows have filled up river gorges of a former period.

Where drift deposits in glaciated country have obliterated prior channels.

Where the river gorge has had its origin in a volcanic fissure.

Where the river gorge is cutting through an intrusion of soft lava or a deposit of volcanic ash.

### Inefficiency of City Streets Causes Loss of More Than 1 Billion

The terrific economic burden imposed by the inefficiency of city streets in handling the complex stream of modern traffic amounts to more than a billion dollars a year, according to estimates recently compiled on the basis of traffic surveys made in several of the largest cities in the United States.

These intensive surveys, many of them conducted by the Albert Russel Erskine Bureau for Street Traffic Research, which is endowed in Harvard University by The Studebaker Corporation, have established a new concept of the relation of traffic congestion to business and the cost of living in American cities.

Anything that threatens to limit the utility of the streets and the convenience of their use serves in equal degree to impair the commercial efficiency of the city, the surveys have disclosed. Ease and cheapness of street use are important factors in conducting any business enterprise. Congestion on the main thoroughfares of a city affects in varying degrees all business activity, and finds its ramifications far down in the foundations of commercial enterprises of all kinds.

The amount of money involved in the operation of various forms of street transportation—street cars, busses, trucks, and horse-drawn vehicles, comes to a huge total in any large city. In Chicago, for example, it is estimated at \$290,000,000 per annum. Considering the magnitude of this operating cost, it is apparent that even moderate reductions in delays will result in tremendous savings.

In the case of Chicago a ten months' survey was conducted by Miller McClintock, director of the Erskine Bureau, showed that as little as a ten per cent reduction in the delays occasioned by traffic congestion would result in a saving to the city of more than \$27,000,000 a year. In New York alone it has been estimated that traffic congestion causes a loss of nearly \$200,000,000 a year.

While traffic experts declare it impossible to fix a definite value on the sum total delay occasioned by traffic

congestion, their surveys have demonstrated that street transport plays a substantial part in the cost of living in every large city. Individuals may be aware of the cost of their personal transportation, but the indirect costs of living to be found in commodity prices resulting from cartage of materials is less well known and its burden less realized.

A study of the cost of transport made by the Chicago survey disclosed that drayage costs in the city on potatoes amounts to 25 to 50 per cent of the freight rates, while in the case of coal it was found that trucking costs from freight car to the consumer's coal bin averaged more than 50 per cent of the shipping cost.

Retail business is vitally affected by street congestion, according to Dr. McClintock. Values being equal, purchases will be made in establishments offering the greatest convenience in the form of accessibility and comfort to customers, for traffic follows the line of least resistance. A recent survey made by the Department of Commerce indicated that as high as 50 per cent of retail establishments in cities over 50,000 in population are affected by inaccessibility resulting from street congestion, and that the volume of business was reduced from one to 20 per cent below normal by this one factor alone.

"Lack of facility for traffic movement and for parking causes a dispersion of business activity that is another factor in increasing the economic burden of traffic congestion," declares the Erskine Bureau head, who added that this factor is the chief threat of street traffic and transportation congestion.

"It is a well recognized fact that there are economic advantages accruing from large scale merchandising and that there are additional economic advantages resulting from the grouping of stores and commercial enterprises of similar type.

The decentralization that is abnormally fostered by unchecked traffic congestion will result in smaller and more scattered retail units and multiplied overhead costs that must eventually be carried by the consumer."

**Motorized Equipment in Michigan Road Maintenance.**—During the past two years the Michigan Highway Commission has replaced practically all horse drawn patrols on trunk line maintenance work with motorized equipment. The one-man tractor-grader and the truck with blade attachment are favored for this work. These are supplemented at intervals by the use of heavy graders drawn by 10-ton caterpillar tractors, and this heavy equipment has been found very satisfactory for reshaping gravel roads and putting them into good condition to be maintained by lighter equipment.

# Highway Estimating and Cost Accounting

Useful Suggestions Given in Paper Presented at Annual Convention of American Road Builders Association

By R. C. JACOB

President, The Juniata Co., Contractors, Philadelphia, Pa.

Those differences of opinion which make horse races and enrich two lawyers in a small community where otherwise one would starve to death are the bane of highway constructors. They never enrich anybody. Because contracts are almost invariably to the lowest bidder, however absurd his bid, and because some surety company, however fantastic his pretensions, will enthusiastically guarantee the faithful performance of his obligation to deliver a certain number of dollars at a price of seventy-five cents or less each, these differences of opinion as to costs hurt not only the foolish bidder but depress the entire industry.

Their effect is always to drive prices downward. The average road builder when preparing his bid reckons first his cost; to this he adds his profit; then he says to himself, "But somebody else will do it for so much!" If he wants the job he must reduce his legitimate profit to an inadequate margin to meet this ruinous competition. If he gets the job he makes a trifle provided he gets all, or nearly all "the breaks." This lowered bid and the award of the contract in consequence stimulates the reckless and ignorant competitor to greater efforts the next time. He reduces his bid still further, thereby giving another turn to the screw. The vicious circle continues. More contractors are driven out of business after a few feverish years by this their own folly and ignorance, than by disasters which could not be foreseen and guarded against. In about twenty-five years the average manufacturer makes enough to permit him to retire; in three years the average road builder loses enough to compel his retirement!

**Advantages of Accurate Cost Records.**—Carefully kept accurate cost accounts, carefully studied as a guide when estimating should do much to remedy this. As no sane man knowingly takes business at a loss his losing bid is generally made because he is ignorant of what his costs will be. While estimating and cost accounting are radically different operations, they are closely related. Knowledge of what an item of work cost in the past always enters into the computation of what it will cost in the future and is always a base from which to proceed. The more a contractor knows of the details of past costs the more intelligently he will estimate just what each step of the project under consideration will cost. A number of varying elements will always enter into construction work, and left to themselves will always result in

differences of opinion as to costs, and will be productive of some erratic bidding; but a carefully compiled record of actual costs, extending over a period of years, based upon close observation and skillful analysis, will have a steady effect upon even these. It will not make bidding uniform but it will give the cautious bidder a sound basis upon which to begin; and will furnish him with an average below which he will realize it is unsafe to go.

We would like to say as we get down to "brass tacks" that we have no intention of trying to tell those contractors who have been in the business for a lifetime and grown rich at it how they should keep their costs and do their estimating. They have their staffs of engineers who have given years of painstaking study to the working out of minutely detailed systems applicable to their own problems. We have no higher ambition than to exchange ideas with those of our friends whose equipment and experience are about like our own. If we can give a worthwhile hint to any of them, or to those who are even newer at the business we will let our elders and betters struggle along as best they can without our help.

**The Two Duties of Cost Accounts.**—Cost accounts have two duties to perform. First they must tell accurately when a job is completed whether it made or lost and how much; secondly, they must tell during the progress of the work whether everything is being done at a sufficiently close approach to the contractor's estimated costs to assure him that the work is moving smoothly and economically. If any one operation is being done at a loss the cost account must make that known while there is yet time to apply the remedy. If the loss progresses and is sufficiently large the contractor will learn of it without the aid of a cost accountant if he cares to wait. Too often when he does wait the knowledge comes as a surprise that takes away his breath and almost all his bank account.

Of course every constructor tries to keep his costs accurately and doubtless thinks he does, but it is highly probable that a surprisingly large percentage deceive themselves unwittingly. They fail to take into consideration all the items of cost, some of which may not appear on the surface of things until long after the job is completed and the balance in the ledger account of it carried to profit and loss. These have to be met; but the contractor who fails to consider them and make preparation to pay them at the proper time will

find himself most suddenly and unexpectedly out of pocket. He is in the position of one who gives a note that is payable at his own bank and forgets all about it. But the bank does not forget, and when the day for payment comes quietly charges up the note saying nothing about it. The depositor will then draw against money that has been taken away from him without his knowledge; and learns of his mistake after his check has been protested and when it is too late.

**The Unseen Expenses.**—What are those items of expense that catch the contractor unaware; eat up his profits; and sometimes devour his business too? If he can ascertain in advance just what they are and about what they will total, and then add the total to the cost of the road and collect for it, and then put aside the money to pay these bills when they are presented he has played absolutely safe. This is just what proper estimating and cost accounting enable him to do; and for this he requires nothing more than common sense and ordinary business prudence and forethought.

After the cost accountant has reckoned the cost of the materials entering into the completed road, the cost of transporting them to the point where they are to be used, the labor of putting them in place, bond and insurance premiums, small tools which are bought for the job and worn out or lost upon it, and the cost of equipment repairs, he has about totalled construction costs. But all the other expenses of doing business must be met out of this construction work. There is no other available source of revenue. Therefore each mile of road built in a year must carry its proper proportion of these costs, also.

The first step in forming an adequate and reliable system of cost accounting and estimating is the assembling and studying of these various other expenses. The old hit-or-miss method used when the business was very young, its overhead trifling, its outlay for plant and repairs negligible, and its salary list so small that it could be met out of the sum needed for incidentals has passed forever into the discard. Unseen expenses used to be met out of profits—when they were sufficient! When they justified the outlay a few dollars worth of repair parts and a few gallons of paint put the plant in the pink of condition. When there were no profits it was taken for granted that there were neither depreciation nor the need for repairs. But with the evo-

lution of the industry in the last few years from its crude beginnings to an impressive and costly aggregation of heavy machinery manned by high priced technical men; requiring for its financing sums that still stagger the imagination of the oldtimers, the raising and managing of which are almost a business in themselves; something better and more reliable than this uncertainty is required. Profits are poor providers. Expenses are real, definite and clamorous. Besides, they are tireless workers. A definite fund must be set aside for them or else they will eat voraciously into capital and wreck the business. Profits are that which remains after the payment of expenses; not a fund out of which uncertain and contingent expenses are to be paid. Failure to grasp the importance and significance of this has driven more than one contractor to the wall.

**The Actual Working Season.**—It must never be forgotten that while actual construction work may not be possible for more than eight or nine months out of the twelve in the greater part of the United States because of adverse weather conditions, that it never rains hard enough to stop the running of interest, freezes tight enough to make depreciation impossible, or snows hard enough to stop salaries. Expenses of certain kinds go on merrily whether the contractor works or goes fishing. He may reduce some decidedly by shutting down but others continue from the mere fact that he is in business. These latter kind are what may be called unseen or hidden expenses. Depreciation is the most striking instance of this. It is going on constantly. But the contractor never feels it until he has to scrap thousands of dollars worth of worn-out equipment and replace it with new and expensive. The additional outlay representing the difference between the old and the new is astounding. If this be considered as a part of the cost of each year's business, which it undoubtedly is, and is provided for by reckoning it in the cost in advance, scrapping and replacing are always so arranged for that the apparent loss is covered and thoroughly neutralized.

**What a Cost System Shows.**—Now, as to putting these theories into practice. If a contractor's accounts have been kept with reasonable care and extend over a period of several years they will enable him to tell with an approach to accuracy that will be near enough for practical purposes just what expenses beyond actual construction costs he must provide for during the coming year. He will know about the mileage he should build in a year and will have to guess as best he can what his business during the coming year will be. This can never be done with perfect accuracy but it is not nearly as difficult to make a workable approximation as at first appears. If he has a plant and organization that should build five miles a year, and that has been his average

for the preceding few years he will have to count on about that for the year that is to come. If he is going to employ all this on only one mile of road in a year he will lose money no matter what his system of estimating. As he is not equipped to build fifteen miles and cannot, considering his normal growth, safely expand to three times his construction mileage at a bound, it would be suicidal to spread his estimated overhead over that latter figure. He therefore divides all his costs for the year by the year's mileage; and as he estimates he adds this sum to his proposals, pro rata.

Depreciation and repair tables will tell him just what he should allow for these items. They are figured on a time basis. In estimating on a given job the estimator makes the best approximation he can of the time it will take to complete it, and the amount of depreciation he must allow for that period for the plant he will operate on it. This must be added in as a cost item.

The estimator must next figure what may be called the "job overhead"—the expenses upon the job not directly chargeable to any one operation but to all. Such are the salaries of the superintendent, timekeeper, material clerk, and engineer if there be any; freights on the plant; premiums on bond and on liability and compensation insurance; and a number of other items that will occur to every practical man. This total must be added to the general overhead total, and the grand total divided pro rata among the various classes of work on the job. Next the sum allotted to each class must be divided pro rata among the units that make up its total.

**Example of Use of Cost Records.**—By way of illustration: A constructor figures that he should build 20 miles of road per year, and that his total annual overhead will be \$20,000; or \$1,000 per mile. He is preparing a bid on a 2-mile job which he figures he should complete, after making due allowance for adverse weather conditions and other causes of delay, in four months. Over the total of these two miles he spreads:

General overhead—2 miles @ \$1,000 per mile	\$ 2,000
Job overhead—salaries, freights, etc.	6,000
Depreciation, 4 months	4,000
	<b>\$12,000</b>

He apportions this as follows:

Construction cost of concrete \$60,000—its pro rata	\$10,000
Construction cost of excavation 8,000—its pro rata	1,600
Construction cost of pipes, etc. 2,000—its pro rata	400
	<b>\$70,000</b>
	<b>\$12,000</b>

If there are 20,000 sq. yd. of concrete in the job and 4,000 yd. of grading the amount to be added to each yard is ascertainable by a simple problem in division, using these figures. This result should be added to the estimated actual construction cost of each unit.

If he has figured his construction cost of concrete at \$2.50 per yard he will therefore add to it for overhead the proportionate sum each yard must carry on the basis of the above figures, which is 50 ct. per yard; and to this total of \$3 he will add his profit. If he figures a profit of 20 per cent he will then list the concrete pavement on his bid at \$3.60 per yard.

Estimating construction costs is a mixed question of accounting, practical experience, keen, careful observation, a thorough understanding of all the difficulties in the way, and an intimate knowledge of the best way to handle them. One word as to the best method to be used here. The unit on which the contractor is asked to submit his bid must not be considered by him as a unit in making up his bid price, but must be split up into as many different operations as enter into the completed unit, and his price figured separately on each of these. As an illustration: He has been asked for price on excavation. The better and more careful practice is to consider all the separate operations that make up a unit of excavation and make up his bid price by estimating first the cost of each of these. He may have to clear; dynamite and drilling may be needed; there may be certain freights on the equipment needed for excavation alone. The fuel costs of this equipment must be figured; and the costs of loading, hauling, spreading and rolling. If the estimator will figure each of these separate parts of the completed unit separately he will certainly reduce the probability of error in his bid.

This same method will of course be necessary, but in even greater detail, in figuring concrete costs. The operation of making and laying the concrete pavement is decidedly more complex than any other operation that enters into the completed roadway. The estimator should analyze this as carefully as he can; figuring the cost of each aggregate delivered at the mixer; the cost of mixing and placing; and he must take also into very careful consideration the possibility of delays in this and their cost to him.

Thus far we have spoken of estimating and cost accounting together as though they were one and the same. The experienced contractor does not confuse them in his mind but he always thinks of them together. Estimating is repeating what his cost accounts have taught him in the past. Without carefully kept cost records extending over a number of years and embracing almost every variety of work the constructor undertakes, estimating is largely a matter of unreliable guess work.

**Cost Accounting Systems.**—But cost accounting is entitled to more than passing notice and deserves separate and special consideration. Each business organization will either make its own system or else adapt one made by somebody else to its own use with the variations necessary to make it fit per-

fectly. The method used is less important than the completeness and comprehensiveness of its data. Every system is found on frequent and detailed reports from the field, and the more exact and comprehensive these are the more perfectly the cost accounting force will be able to figure in detail the exact costs of just what is being done.

The field should make its report at the close of every day's work. It should tell exactly the labor cost of that day on each item making up each unit as the estimator figured it. In the matter of excavation for example, the report should give the most careful estimate possible of the yardage of earth moved, and tell between what stations this work was done. It should tell the number of hours of labor, hauling, etc., on clearing, loading and every other constituent operation of excavation. To this the cost accountant in the office can add the pro rata of overhead, etc., and by careful figuring tell from day to day whether the job is making or losing on each operation, whether there is an overrun of material, and all the other obscure features of the work that need careful checking from time to time in order that the possibility of loss may be reduced to the minimum.

**Essentials of Estimating and Cost Accounting.**—In conclusion, if we were asked to summarize the essentials of estimating and cost accounting we would say that this reducing every operation to its lowest terms, splitting it up into every separate operation that enters into it, estimating on these separately, and having cost records that itemize them separately also is most important to every constructor who is in search of the safest and most accurate method to be used. Methods, however, are only helpful and worthwhile when carefully and intelligently followed. We had an old friend in the highway construction business who once asked us to check his bid. It was a macadam job that was bound to go at a low price. We called his attention to his omission of his bond premium, the premiums on his compensation and liability insurance, and his own salary. He had no office overhead, as we remember. He told us he had omitted these items purposely because he said, if he included them in his costs he could not possibly get the job.

That may sound like a humorous story but it is sadly true. This contractor has since gone out of business and is now employed in another line on a salary. We know of no man who has been in the business who is more greatly missed. Material men, equipment men, and a certain surety company, have often told us exactly, in dollars and cents, how much they miss him. A bank president speaks of him as his dearest friend, because he cost him thirty thousand dollars and he was very dear at that price.

We mention this incident as illustrat-

ing more pointedly than any other that ever came under our notice what is bound to happen when the bidder thinks that overhead is payable out of profits, and that bids should be made on the basis of actual construction costs and nothing else. These items of overhead and hidden expenses cannot be omitted without the gravest danger of disaster. They are figured carefully in every other line of business but seem to be studiously ignored in the construction industry.

We believe that an exact knowledge of costs, if that knowledge be acquired in time, will do much to remedy this and to stabilize the business. All contractors of necessity learn a great deal about costs, but not always at the most advantageous time. The knowledge should be acquired in advance and not after the completion of the work and in the bankruptcy court.

A wave of low, reckless and irresponsible bidding has swept the country. We question if the highway industry taken as a whole would show any profit in the past year if a proper reckoning of costs could be made.

Some of us have resolutely avoided this maelstrom of cut-throat bidding. Many have been bitten by the bug "I must get a job," but have found out when too late that instead of being "bitten" they were "stung."

**Causes of Low Bidding.**—The lack of careful cost keeping, inaccurate estimating, and often poor guess work, are the cause of much of this low bidding. Premium greed on the part of the bonding companies and their agents give this low bidder a false appearance of responsibility. The clause "That contracts shall be awarded to the lowest responsible bidder" is never used and the ignoring of it fastens the inevitable loss more firmly upon the unfortunate bidder. This clause is like the eighteenth amendment—it never yet took anything away from anybody! If it is to be so consistently ignored it should be cut out of the specifications. All of these causes combined make rough sailing and the highway man's boat is often upset. The persistence of this mathematical brain storm threatens disaster to the industry. It is the duty of the level-headed and conservative in the industry; and in those which are closely allied to it to take some firm stand and adopt some drastic measure to end it. We fully believe that highway departments are willing to pay cost plus profit, and that no reputable commissioner is seeking bargains at a price detrimental to the business. Then, fellow contractors, it is up to us not to make of ourselves "pure damn fools."

**Illinois Now Has Gas Tax.**—The Illinois Legislature has passed a bill fixing a 2 ct. tax on gasoline. The act goes into effect on Aug. 1. New York and Massachusetts are now the only states not having gasoline taxes.

## Last Year Gasoline Taxes Yielded \$187,000,000

Gasoline taxes yielded a net revenue of \$187,603,231 in 1926, according to data collected by the Bureau of Public Roads of the United States Department of Agriculture from the various states. A tax was imposed in all but four states at rates ranging from 1 to 5 ct. per gallon, the average rate being 2.38 ct. The tax collections indicate that nearly eight billion gallons were consumed in the states imposing the tax and it is estimated that nearly two billion gallons were used in the four states in which no tax was imposed.

The revenue from the tax was allocated as follows: \$129,441,520 for state highways, \$43,609,479 for county and local roads, \$5,238,869 for payments on road bonds and \$9,313,363 for miscellaneous purposes.

Fewer changes were made in the rate of tax than in other recent years. In Kentucky the rate was increased from 3 to 5 ct., in Mississippi from 3 to 4 ct., in North Dakota from 1 to 2 ct., and in Virginia from 3 to 4½ ct. Other increases which became effective after the close of the year were an increase in Alabama from 2 to 4 ct. and in Montana from 2 to 3 ct.

	Net tax receipts	Rate of tax on Dec. 31, 1926, ct.
Alabama .....	\$ 2,558,651	*2
Arizona .....	978,264	3
Arkansas .....	3,585,304	4
California .....	16,502,123	2
Colorado .....	2,091,749	2
Connecticut .....	2,689,372	2
Delaware .....	390,414	2
Florida .....	11,431,486	4
Georgia .....	5,658,140	3½
Idaho .....	1,122,217	3
Illinois .....	8,971,741	3
Indiana .....	4,842,427	2
Iowa .....	4,308,388	2
Kansas .....	4,935,078	5
Kentucky .....	2,708,567	5
Louisiana .....	1,823,346	2
Maine .....	2,293,854	2
Maryland .....	10,081,776	0
Massachusetts .....	4,804,688	2
Michigan .....	4,088,200	2
Minnesota .....	5,661,145	4
Mississippi .....	870,712	2
Missouri .....	3,039,927	12
Montana .....	405,818	2
Nebraska .....	768,582	4
Nevada .....	762,851	2
New Hampshire .....	7,786,473	0
New Jersey .....	988,493	3
New Mexico .....	13,257,266	0
New York .....	6,212,409	4
North Carolina .....	3,333,829	2
North Dakota .....	511,896	2
Ohio .....	11,781,782	1
Oklahoma .....	1,924,758	2
Oregon .....	4,496,968	5
Pennsylvania .....	1,924,758	3
Rhode Island .....	3,852,524	1
South Carolina .....	5,226,886	3
South Dakota .....	1,258,009	3½
Tennessee .....	553,093	2
Texas .....	5,855,670	4½
Utah .....	3,482,093	2
Vermont .....	2,922,675	3½
Virginia .....	5,209,805	2
West Virginia .....	568,589	2½
Wisconsin .....	1,015,193	2
Wyoming .....		2½
District of Columbia .....		2.38
Total .....	\$187,603,231	

\*Changed to 4 ct. on Jan. 4, 1927.

†Changed to 3 ct. on Jan. 1, 1927.

# Standard Sizes of Crushed Stone

What Is Being Done in Way of Standardization Outlined in Paper Presented at 10th Annual Meeting of National Crushed Stone Association

By F. H. JACKSON

Engineer of Tests, U. S. Bureau of Public Roads

Practically every one having to do with either the production or the use of crushed stone will concede at least the theoretical advantages which may be derived from the standardization of sizes. The wide divergence of existing standards of construction, however, coupled with a natural reluctance on the part of engineers to change their practice simply to comply with a national standard, has made progress in this field very slow. The unsystematic development of the various types of bituminous roads has resulted in a demand for a large number of sizes of stone for a comparatively small number of distinct types of construction, the variations often being of academic rather than practical significance.

**Large Number of Sizes of Crushed Stone Not Needed.**—We may classify these variations in requirements in two groups, (1) those due to distinct differences in engineering practice for a given type of construction, and (2) those very small differences in requirements which are in reality meaningless, but which frequently cause considerable trouble. As an illustration of the first class, a survey of 27 current State specifications for penetration bituminous macadam reveals that there are now specified as many as 10 different sizes of stone for use in the penetration course alone, varying all the way from a 1 to 2 in. size to a 2½ to 3½ in. size. As an illustration of the second class, the requirements for size of chips for bituminous macadam in current specifications show an inexcusable number of slight variations in size, such as ¾ to 1 in., ¾ to 1½ in., ¾ to 1½ in., and other sizes.

Making every allowance for variations in size necessitated by difference in quality, it is yet obvious that the multiplicity of requirements in force is not only unnecessary and confusing but also works a hardship on the producer, increases the cost of production, and so tends ultimately to increase prices. On the other hand, it must be remembered that it is the engineer in charge of construction and not the producer of the material who is responsible for the quality of the work and he can not be expected to abandon a size with which he has perhaps had many years' satisfactory experience unless he is convinced that the standard size will prove just as satisfactory. And herein lies the greatest difficulty. It is with the engineers and not the producers. Experience with producers in general shows that they are willing to supply

what the engineers want, provided the latter will only agree as to just what they do want.

The road materials committee of the American Society for Testing Materials, through its sectional committee on standard sizes of broken stone, broken slag, and gravel, has considered this problem for a number of years and has prepared tentative specifications for commercial sizes of broken stone. These tentative specifications were prepared after an exhaustive study of existing specifications with a view to the selection of the minimum number of primary sizes of crushed stone which would supply the engineers' needs and at the same time eliminate the many small variations in requirements which had no justification other than that they represented the ideas of individual engineers or groups of engineers. This was no easy task because it involved not only the elimination of many sizes for which the committee felt standard sizes could be substituted, but also because it necessitated a careful study of the various factors which influence the efficiency of plant-screening operations in order that the size limits and tolerances specified might be practical from the standpoint of economical production. The problem required a careful balancing of these practical limitations against theoretical requirements.

**Survey Indicates Factors Affecting Screening.**—Before proceeding to a discussion of the proposed standards, it may be of interest to review briefly the results secured from a rather extensive survey of crushed stone plants made by the Bureau of Public Roads several years ago. The survey included over 100 representative commercial plants situated in the New England, Middle Atlantic, and Ohio Valley States. The information secured, while bearing particularly on the screening operation, included data relative to crushers, their number, type and size, speed and arrangement of conveyors, etc. The screen data included the number, type, and arrangement of screens; the nominal as well as actual size of perforations; the length, diameter, pitch, and speed of revolving screens with the number and length of each section; arrangement of jackets, etc. A record was made of each commercial size produced by the plant with the screen installation as indicated at the time of inspection. This record included the nominal size limits for each product, the name and number under which it was sold, and the specifications it was

supposed to meet. Finally, a representative sample of each size was secured from a stock ready for delivery and a screen analysis was made with laboratory screens having circular openings.

From these data it was possible to determine the efficiency of each screening operation at the time of inspection in so far as it was affected by the screens themselves. Other factors which affect screening efficiency, such as fluctuations of the feeding rate and moisture on the stone, were noted and their effect on the particular material selected for sampling determined as nearly as possible. It may be of interest to summarize briefly the conclusions which it was possible to draw from this survey, and they may be stated as follows:

1. The length of a revolving screen influences the grading of the screened product to a marked degree.

2. Within the relatively narrow limits usually found in plant installations pitch and speed of revolving screens apparently have no material influence on grading, probably on account of other predominating factors, such as fluctuation in the rate of feed of stone to the screen, which it is impossible to control in a practical way.

3. The effect of oversize holes due to wear of the screen is practically negligible in view of the relatively large amount of stone held on a revolving screen which theoretically should have passed through it.

4. Small amounts of oversize stone sometimes found in products screened through holes of certain nominal diameter usually are due to faulty bin or chute construction, lack of repair, or other deficiencies in the storing or handling of the material.

5. The grading of the screened product can not be controlled with any degree of certainty by simply specifying the size of openings in the revolving screens over which and through which it shall pass.

6. It is neither practical nor necessary to specify that all material retained on and passing revolving screens of certain sizes shall lie between laboratory screens of the same size.

7. Laboratory screens may be used to control the grading of the plant product if a reasonable tolerance is allowed, that is, one wide enough to cover the recognized inefficiency of the revolving screen and yet close enough to insure sufficiently well-graded materials.

8. Inspection of the results of hundreds of screen analyses indicates that as much as 5 per cent of material should be allowed larger than the size of perforations in the revolving screen through which the product is supposed

to pass, and as much as 15 per cent generally should be allowed smaller than the size of the perforations in the revolving screen upon which it is supposed to be retained.

**Plant Limitations Recognized.**—The last conclusion applies, of course, only to products sized with revolving screens and presupposes an adequately designed plant and efficient operation. It applies to the so-called primary sizes only, that is, those sizes the upper and lower limits of which are close together as  $\frac{3}{4}$  to 1 in. With combined sizes, such as are used as concrete aggregate,  $\frac{3}{4}$  to 2 in. for example, the tolerance on the lower limit may and should be materially reduced.

With regard to the method of specifying the sizes desired, there are still many engineers who believe that it is necessary to tell the producer just what plant screens to install in order to obtain the sizes they desire. The operator of the average commercial plant is in a much better position to decide on the particular screen installation he needs than the engineer, who should specify only the size or sizes desired in such a manner as to admit of but one interpretation; that is, by reference to laboratory screens. It then becomes the operator's duty to study his installation so as to produce the material in the most efficient manner. Viewed from this angle, the object of the 5 and 15 per cent tolerances just mentioned is simply to recognize the practical limitations beyond which it is impossible to carry efficient operation without greatly increasing the cost.

The facts which were brought out by the survey were of course available for the use of the committee on standard sizes of the American Society for Testing Materials, and form the principal basis of the committee's recommendations as regards tolerances in their proposed specification.

**Five Standard Sizes of Crushed Stone Proposed.**—The committee was, at the outset, confronted with the necessity of reducing the number of primary sizes to a minimum consistent with sound engineering practice. Moreover, it was recognized that the limits of the various primary sizes should not overlap, and when taken together should represent the entire output of a plant. It was also felt that if possible the number of primary separations should be limited to five, due to the greatly increased cost of producing more than five primary sizes in one plant at one time. It is interesting to note in this connection that many large producers replying to a recent invitation from the National Crushed Stone Association to criticize the proposed standard, stated that from the standpoint of economic production, the number of primary sizes should be limited to five.

The committee also considered very carefully the question of nomenclature. What would be the simplest and most easily understood method of designat-

ing sizes? At present there are many systems in use, to the utter confusion of everyone. We have No. 3 stone; we have 1-in. stone, and we have pea stone, to mention three methods of designating sizes and these designations do not always mean the same thing in different localities. No. 1 stone in one state may be described as No. 3 stone in an adjoining state. What does the purchaser mean when he asks for a car of 1-in. stone? Does he mean a maximum size of 1-in. or an average size of 1 in. and if so what are his upper and lower limiting sizes?

The committee after carefully considering the various systems in current use decided that the simplest as well as most definite method of designation would be to specify both the upper and lower limiting sizes, as, for instance,  $\frac{3}{4}$  to  $\frac{3}{4}$  in. size,  $\frac{3}{4}$  to 1 in. size, etc., which together with a standardized schedule of tolerances and intermediate requirements would give a clear understandable designation, provided a method could be agreed upon for measuring size. There has been a considerable difference of opinion on this point and it has been difficult to bring about agreement between those who favor the square mesh on account of its application in the design of concrete by the fineness modulus method, and those who favor the round hole because it has been used for many years for measuring the size of crushed stone for bituminous road work, and in general is considered a more accurate measure of size than the square opening. However, the committee on road materials of the American Society for Testing Materials, which contains representatives of both sides, last year went on record as favoring the round aperture, and with this precedent the sectional committee on standard sizes decided to submit its tentative schedule of sizes with this method of measuring as the basis. In other words, when we say  $\frac{3}{4}$  to  $\frac{3}{4}$  in. size, we mean that portion of the product of the crusher at least 85 per cent of which will be retained upon a laboratory screen having circular openings  $\frac{3}{4}$  in. in diameter and not more than 5 per cent of which will be retained upon a laboratory screen with circular openings  $\frac{3}{4}$  in. in diameter.

On the basis of five primary sizes as the maximum limit and after careful study of existing specifications, the committee proposed the following divisions of the crusher run from 0 to  $3\frac{1}{2}$  in.

0 to  $\frac{3}{4}$  in.  
 $\frac{3}{4}$  to  $\frac{3}{4}$  in.  
 $\frac{3}{4}$  to 1 in.  
 1 to  $2\frac{1}{2}$  in.  
 $2\frac{1}{2}$  to  $3\frac{1}{2}$  in.

These separations are to be on the basis of laboratory screens with round openings. Assuming that, in general, stone will crush in such a way that the percentage of the total crusher run passing any particular size screen will be in proportion to the size of the opening—that is, conforming to a straight-

line grading—then the relative percentages of the total crusher run obtained in each of the five primary sizes would be about as follows:

0 to  $\frac{3}{4}$  in.—10 per cent.  
 $\frac{3}{4}$  to  $\frac{3}{4}$  in.—15 per cent.  
 $\frac{3}{4}$  to 1 in.—15 per cent.  
 1 to  $2\frac{1}{2}$  in.—35 per cent.  
 $2\frac{1}{2}$  to  $3\frac{1}{2}$  in.—25 per cent.

The relative percentages of the various sizes will, of course, vary in individual cases with the kind of stone, type of crushers, and amount of recrushing. For general conditions, however, and assuming that stone above  $3\frac{1}{2}$  in. is rejected and recrushed, the above may be considered an indication of average results. A recent report based on elaborate plant tests, substantially confirms the above figures.

**Proposed Sizes Meet All Ordinary Requirements.**—The above system of sizes was considered with a view to ascertaining to what extent each size would be available to the engineer and how the sizes could be combined, remembering that for each primary size a tolerance of 15 per cent is allowed on the lower limit and 5 per cent on the upper limit. The problem of establishing standard size limits so as to care for the entire output of all plants with a minimum of waste at all times is, of course, a hopeless one. There are uncontrollable fluctuations in demand which may cause a certain size to be in great demand one month and a drug on the market the next. There may be a difference in the demand for stone of different kinds. The supply of limestone in certain sizes required for road work or as concrete aggregate may be greatly affected by the demand for flux stone or agricultural limestone, while trap rock would not be affected by the latter demands. It is obviously impossible to carry standardization to the point where a uniform standard of plant practice is possible. Every plant and every producing district has its own peculiar problems and the best that standardization can do is to provide a common measure for the use of the engineer in making known his needs to the producer so that the latter will know exactly what the former wants and the former will know exactly what the latter has to offer.

Considering the uses to which the several suggested sizes may be put, let us take first the  $\frac{3}{4}$  to  $\frac{3}{4}$  in. size. This is commercial  $\frac{1}{2}$ -in. stone, very largely used in road work as chips in bituminous macadam construction by the penetration method, in certain grades of bituminous concrete, as a surface dressing, and in maintenance work. It was felt that a tolerance of 15 per cent on the lower limit gave a reasonably well sized product, and was liberal enough for economic production. The next size,  $\frac{3}{4}$  to 1 in., is commercial 1-in. stone, with the same tolerance of 15 per cent. It may be used alone as the intermediate course in bituminous macadam, or

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in combination with the  $\frac{1}{4}$  to  $\frac{3}{4}$  in. size in certain grades of bituminous concrete or as an aggregate in Portland cement concrete, where the maximum size must not exceed  $1\frac{1}{4}$  in. A combination size made up of the  $\frac{1}{4}$  to  $\frac{3}{4}$  in. size and the  $\frac{3}{4}$  to  $1\frac{1}{4}$  in. size, each of which complies with specifications for that size, may reasonably carry a somewhat lower tolerance than 15 per cent—10 per cent at most and possibly 5 per cent in the case of concrete aggregate where a relatively large percentage of the  $\frac{3}{4}$  to  $1\frac{1}{4}$  in. size should be used in the mixture.

The next size,  $1\frac{1}{4}$  to  $2\frac{1}{2}$  in., is proposed for use in macadam road construction, either penetration or waterbound. Objection has been raised to this size for penetration macadam on the ground that a larger size, say, 2 to 3 in., would give better results and that the maximum size stone should be limited only by the depth of the course. Reviewing the several State highway department specifications, we find a wide divergence of practice. Out of 27 State specification standards, there are 3 with a maximum size of 2 in., 12 with a maximum of  $2\frac{1}{2}$  in., 7 with a maximum of  $2\frac{3}{4}$  in., 5 with a maximum of 3 in., and 1 with a maximum of  $3\frac{1}{2}$  in., the latter to be used only in courses exceeding 3 in. in depth. This indicates the difficulties in the way of pleasing everybody. It may be suggested that a compromise could be made by raising the upper limit to 3 in., without realizing that to do so would throw the entire specification out of balance by eliminating the  $2\frac{1}{2}$ -in. separation which is insisted upon by the users of concrete aggregates. At the present time the committee is inclined to adhere to the present limit of  $2\frac{1}{2}$  in. for bituminous macadam where the course is less than 3 in. in depth and to suggest the  $2\frac{1}{2}$  to  $3\frac{1}{2}$  in. size where the course is greater than 3 in. in depth.

**Standard Sizes Suitable for Concrete Aggregate.**—We now have three primary sizes which together represent the run of the crusher from  $\frac{1}{4}$  to  $2\frac{1}{2}$  in. When properly combined, these three sizes may be used to produce an ideally graded aggregate for concrete for pavements where the maximum size is  $2\frac{1}{2}$  in. Just what constitutes an ideal grading for coarse aggregate for pavements makes an interesting problem for discussion, both from an economic and an engineering standpoint. Recent investigations made by the Bureau of Public Roads in co-operation with the New Jersey State Highway Commission indicate that the yield of concrete from given volumes of the constituent materials is greatly influenced by the grading of coarse aggregate. As an illustration, it was found that in the case of a 1:1 $\frac{1}{4}$ :3 $\frac{1}{2}$  mix, using crushed trap rock as coarse aggregate, a stone graded uniformly from  $2\frac{1}{2}$  in. to  $\frac{1}{4}$  in. in size required 6.18 bags of cement per cubic yard of finished concrete as com-

pared to 6.72 bags required when the material under 1 inch in size was omitted—a saving in cement of about one-half bag per cubic yard. It is true that a considerably greater weight of stone was required in the case of the well-graded aggregate than in the case of the poorly graded material, so that from a strictly economic point of view the gain in cement would be somewhat offset by the additional stone required. The economic aspects of concrete proportioning have not received the attention that they should.

If we assume for the moment that the ideal grading curve for stone between  $\frac{1}{4}$  in. and  $2\frac{1}{2}$  in. in size is approximately a straight line, which ac-

$1\frac{1}{4}$  to  $2\frac{1}{2}$  in. size—60 per cent.  
 $\frac{3}{4}$  to  $1\frac{1}{4}$  in. size—25 per cent.  
 $\frac{1}{4}$  to  $\frac{3}{4}$  in. size—15 per cent.

A Study of the Mechanical Analysis of Crushed Stone, the Crushed Stone Journal, July 1, 1926, published by the National Crushed Stone Association, Washington, D. C.

cording to Taylor and Thompson is the condition of maximum density it would be necessary to mix the three commercial sizes in approximately the following proportions:

This is very nearly the ratio in which these sizes are produced in the normal crushing process, and would therefore be the most economical way for the producer to ship, provided he did not have a heavy demand for  $\frac{1}{4}$  to  $\frac{3}{4}$  in. size, which is often the case. However, the point to be emphasized here is that in concrete work it is highly important to have a uniform grading of coarse aggregate from day to day if satisfactory results are to be obtained. This rule holds irrespective of the method used in designing the mix. As a matter of fact, it is even more important viewed in the light of some of the new theories of concrete design which have been advanced due principally to the effect of variations in gradation on the workability of the concrete and consequently on the amount of water which must be used in order to properly place the mix. Variation in the amount of water used in the mix will affect the strength of the concrete, resulting in a non-uniform product. From the viewpoint of the producer it is of great importance to maintain uniformity in the gradation of aggregates for concrete even though the specification may allow a considerable variation in some of the intermediate sizes. Rigid attention to such details will do more to overcome the natural disadvantages of crushed rock as compared to certain other aggregates than will any other one thing and will at the same time insure better concrete.

The remaining size in the crusher-run product is from  $2\frac{1}{2}$  to  $3\frac{1}{2}$  in., and would be available for use either as base course in waterbound or as bituminous macadam for courses over 3 in. in depth. In times of heavy demand for the smaller sizes, this size could, of course, be recrushed as desired.

**Problem Not Yet Entirely Solved.**—

The original tentative standard specifications of the American Society for Testing Materials have been amended once by the insertion of a  $0\frac{1}{2}$ -in. size to provide stone for Topeka-type pavement. Many additional changes have been suggested both voluntarily and in response to inquiries sent out by the committee. Among them is a request for a commercial  $\frac{3}{4}$ -in. stone, from  $\frac{1}{2}$  in. to 1 in. in size, for use in tar macadam. The sponsors for this size claim that the  $\frac{3}{4}$  to  $1\frac{1}{4}$  in. size is too large for intermediate-size stone in bituminous macadam. Here again engineering opinion causes difficulty in the adoption of a rational standard, because it can readily be seen that the  $\frac{1}{2}$  to 1 in. size has no place in the system as above outlined.

Strong representation has also been made by certain eastern groups that a  $\frac{5}{8}$ -in. limiting size be substituted for the  $\frac{3}{4}$ -in. limit. This size is very largely used in the East now as the lower limiting nominal size for cement concrete aggregate, and there seems some merit to the contention that with the  $\frac{1}{4}$ -in. lower limit there is danger of obtaining too high a percentage of small stone which makes a very harsh concrete, difficult to finish properly. The above illustrations are given simply to show that the problem has by no means been solved and will require a great deal more work on the part of intelligent, sympathetic representatives of both the producing and the consuming interests before it is solved.

It should not, however, be assumed that no progress has been made since this matter first came up for discussion. The sizes as proposed have been adopted as tentative by the American Association of State Highway Officials, the Federal Specification Board and the Asphalt Association. It will be seen, therefore, that the specifications have advanced considerably beyond the initial stage. The specifications as adopted by these agencies, however, with the exception of those of the Federal board, are in the nature of typical rather than governing specifications, and are in no sense mandatory.

In conclusion, there seem to be three possible courses which may be followed toward the ultimate solution of this vexing question. We may work for the standardization of the suggested series of sizes, or failing that, suggest other sizes which may be substituted therefor; or failing that, abandon all idea of adopting a national standard, acknowledging that the question of the actual sizes to be used is a problem for each producing district to work out in conjunction with the consumers it serves. In the latter event, the committee of the American Society for Testing Materials would confine its attention to the standardization of methods of designation, standard tolerances and standard methods of measuring size.

# The Highway and the Laboratory

Activities of Bureau of Standards Outlined in Address Presented Before the Highway Research Board

By DR. GEORGE K. BURGESS

Director, U. S. Bureau of Standards

The problems of the highway as we understand them today are of recent origin and have developed hand in hand with the motor vehicle. Not very long ago the finest type of country highway was constructed of waterbound macadam, while some of our best city streets were paved with a thin sheet of asphalt laid with little or no foundation. In those days the problems of the highway were simpler than they are today and highway engineering as a separate profession scarcely existed. A few years ago it was far cheaper and quicker to build a road than to lay a railway track. Today conditions are reversed. In those days roads followed the natural contours, and if steep grades were involved the horses simply stopped for a rest at the top and used the water trough at the foot of the incline. Now, grades and curves must be reduced and if possible eliminated, dangerous intersections must be avoided, and roads banked for high-speed traffic. Highways must have long life, because the detouring of a large volume of traffic on a main thoroughfare is a difficult and expensive matter.

Naturally, I want to talk to you about things of interest in your profession, and I propose to go over very briefly some of the activities of the Bureau of Standards which tie up directly and indirectly with modern highway problems. These problems relate to the materials of highway construction, their testing, definition, and improvement; markings and lighting, including methods of measurement and simplification; the characteristics of motor vehicles, including limitations as to performance; as well as the development of specifications for materials, highway accessories, motor vehicle performance, and rules for safety of operation and traffic control.

**Cement and Concrete.**—All of you are interested in Portland cement and in Portland cement concrete, either directly as actual producers or users or indirectly through competitive materials. The bureau tests a great deal of the cement purchased by the Government. For this purpose it maintains three branch laboratories (Northampton, Pa.; Denver, Colo.; and San Francisco, Calif.) which are devoted almost entirely to the inspection, testing, and shipping of cement on Government purchases in these regions. This service is augmented by the cement laboratory of the bureau in Washington. In addition to this inspection service, these laboratories make studies of the proportioning

of cement from local materials in connection with preliminary studies of Government construction. From this experience data are accumulated which are of value in preparing and revising specifications, such as that for Portland cement of the Federal Specifications Board and the American Engineering Standards Committee. At this point I venture to suggest the very great desirability and advantage of maintaining throughout the country a uniform standard of quality of this material, cement entering so universally as a constituent in road construction. Here the laboratory and highway are most closely linked together, and divergence of practice makes for increased costs of construction and difficulty of distribution.

The Portland Cement Association, through an associateship at the bureau established two years ago and now comprising 10 men, is studying those very necessary problems, what is Portland cement? and what happens when water and solutions of salt are allowed to react with it? Three publications have already been issued by this group. The bureau has maintained since 1910 an experimental cement plant in which a number of studies in connection with these problems have been carried out.

**Design of Concrete Mixtures.**—Many improvements have been made in recent years in the design of concrete mixtures, with particular reference to the grading of the aggregate and the ratio of water to cement to be used. But further work must be done. So far as an average cement has been used in such investigational work, or an assumption has been made that the results developed with one cement will apply to all others. The bureau has been applying these laws of concrete design and water-cement ratio to different cements and finds that these laws are not applicable to all.

The study of the use of concrete for mine stoppings is of interest to you in view of your concern with impact testing of concrete. In co-operation with the Bureau of Mines there has been constructed a heavily reinforced concrete chamber, one end of which can be closed with differently designed concrete slabs. Graded charges of black powder are set off in the chamber, developing different impacts, which are observed, as well as the strain developed in the slabs. The first series of tests is now under way.

You have possibly noted in the engineering journals reference to the bureau's co-operation with Engineering

Foundation in the testing of the 60-ft. high experimental concrete arch dam at Stevenson Creek, Calif. This, while possibly not of direct interest to you, is illustrative of the type of work which the bureau does in its concrete investigations. Such co-operative work may be further illustrated by that now being carried out with the Common Brick Manufacturers' Association of America, the Hollow Building Tile Association, and the National Terra Cotta Society in the studies of the uses of their materials in connection with mortars and concrete.

**Quick Setting Cement.**—The high-alumina cements and the quick-hardening Portland cements are being studied, as well as concrete made from high-alumina cements, both by members of the bureau staff and associates from industry. These types of material are mainly of interest in special and repair work. May I mention in this respect that the bureau issued a publication dealing with the high-alumina cements four years before they were on the market. Two years before they were on the market it issued its Technologic Paper 197, giving the properties of cements of this type made in its own cement plant.

The bituminous and other laboratories of our chemistry division have worked on asphalt, and the Federal Specifications Board has issued specifications covering asphalt, road oil, and similar materials.

**Elimination of Excess Varieties.**—The division of simplified practice of the bureau is one with which a number of you have been in direct contact and on whose committees I know a number of you have served. The first piece of work handled by this division and its first publication deals with the elimination of excess varieties of paving brick. As a result of the first conference, attended by a number of highway engineers, the number of varieties of paving brick was reduced from 66 to 11. A year later these 11 were reduced to 7. The second year later one more variety was eliminated, and two years later still another variety was eliminated. However, as a result of investigational work done by the Bureau of Public Roads, it would appear that at the next session of the conference it may be found desirable to replace one or more varieties. Other items that have been considered by this division of interest to you would be simplification of builders' hardware, steel barrels and drums, steel reinforcing bars, sheet steel, concrete

building units, and shovels, spades and scoops.

**Testing Bridge Members.**—Several years ago the bureau developed a new type of strain gauge, in which the displacement is indicated by changing the pressure on a pile of carbon disks whose electrical resistance is thereby altered. This arrangement makes it possible to construct instruments which follow accurately very rapid changes in stress. The apparatus has the further advantage that readings may either be read from an electrical instrument or be recorded photographically at any convenient location. For example, it is entirely practicable to mount the gauges on relatively inaccessible members of a bridge structure and place the reading or recording apparatus on the ground at any distance desired. These gauges have found use in a great variety of problems, including the study of live stresses on bridges, both for highway and railway use and street railway joints.

A set of the gauges was prepared in 1923 for the Iowa State Highway Commission and has been used very successfully in an investigation carried out by the commission in co-operation with the Iowa State College. These gauges may also be used simultaneously as resistance thermometers, and they are being used, as well as to measure strains in the Stevenson Creek Dam.

Our investigations of the strength of structural steel for bridges have yielded many valuable results. Take, for example, the work on the columns of the Delaware River Bridge. Here a new type of construction was involved and there was some question as to the safe loads which certain members could stand and as to the way in which failure would take place. Specimens of the construction were tested to destruction in the 10,000,000-lb. testing machine at the bureau. As a result of the work a large saving in steel was made possible.

**Street Railway Track.**—Our work in co-operation with the American Electric Railway Association and other national organizations on the most durable joints for street-railway tracks is of importance to the highway engineer, because when track work must be done on a street-car line it means tearing up the roadway. Every type of welded joint in common use is being investigated. For a part of this work we are employing a special impact machine. A heavy hammer is dropped several times a minute on the joint. The specimen rests on a spring-supported anvil, and the number of blows which the joint can stand is an indication of the excellence of the weld. Supplementary tests of the material are also made.

**Efficiency of Tires.**—Turning now to the motor vehicle, one of the problems that concerns all of us is the life efficiency of tires. With a view to aiding in the formulation of tire specifications for the Government, the bureau has carried out a long series of tests, still

under way, on the abrasion of tires and the relative power losses of various types of tires. As a result the Government purchases are now on a much more satisfactory basis than formerly.

One of the most serious problems which confronts the highway engineer today is that of caring for the ever-increasing use of our roads by motor trucks. We are carrying loads that would have been unbelievable a few years ago at high speeds over ordinary highways. The wear and tear on the road are tremendous. In this connection it is important to make sure that trucks are not overloaded. The necessity for enforcing regulations against overloaded trucks has created a demand for portable wheel-load weighers. Several such scales are now on the market. The bureau has investigated the problem and has prepared specifications governing the construction and use of these portable weighing machines.

Our automotive section has also co-operated with several States in working out satisfactory rules for rating motor trucks for purposes of taxation.

**Braking of Motor Vehicles.**—Among the foremost problems of highway control is that of safe and adequate braking control of vehicles. Some years ago the bureau designed and put in service a type of recording accelerometer intended to record the performance of motor-vehicle brakes in operation on the road. An extended study of methods of conveniently and accurately measuring this quantity was made. Later a simple and convenient indicating accelerometer was designed, and with these instruments the braking ability of several hundred typical motor vehicles of all classes selected at random from traffic have been measured. Something like a thousand instruments are now in use by State and municipal authorities and others interested in brake performance, for the control of brake conditions in the interest of public safety or for more extended study of conditions in regard to this phase of vehicle operation.

**Vehicle Road Performance.**—Among instruments applicable to the vehicle is another, or rather a combination of instruments, designed to make a complete and permanent record of the essential elements in the road performance of a vehicle. This equipment has a group of 16 recording pens each drawing an independent record on a single roll of paper. These various records include ground speed, wind speed, wind direction, manifold pressure, oil, water, and rear-axle temperature, rate of gasoline flow, acceleration, etc. From such a record, taken over a comparatively short course, an analysis may be made of all the more important characteristics of the vehicle as regards its performance on the road.

**Motor Fuel Characteristics.**—The Bureau of Standards several years ago undertook a comprehensive study of the effect of motor-fuel characteristics on

the over-all consumption of fuels in motor vehicles. The initial question propounded was "What grade of gasoline as regards volatility will assure the maximum number of car miles per barrel of crude oil consumed in its production?"

There is, of course, a necessary mutual adjustment between the characteristics of the average fuel and those of the average vehicle and such an adjustment takes place more or less automatically, as a result of supply and demand. There is much to be gained in general efficiency if the adjustment can be arrived at which yields the maximum amount of transportation per dollar of cost.

The definite answer found to the initial question stated above was that the least volatile or heaviest fuel which could be successfully used gives most miles per gallon of crude consumed and presumably per dollar of cost.

Other questions were raised, therefore, as to what factors place limits on the use of heavier and cheaper fuels. The more important of these are dilution of oil and difficulty of starting the engine. Both these problems have been investigated and most of the outstanding technical questions regarding them have been investigated, and most of the out-broad problem of mutual adaptation of fuel and engine are also being investigated.

**Brake Performance.**—In the important field of highway safety the Bureau of Standards has accomplished several results which may be of interest. Several years ago there was begun an investigation of brake-lining materials, primarily for the benefit of the Government as a purchaser of these materials. The work thus begun led to co-operation with manufacturers and in some three years resulted in an increase of about 300 per cent in the useful life of the average brake lining. This study of materials led to a study of the behavior of brake linings and of brake mechanisms in service, the latter resulting in the collection of data from which a national brake safety code has been drafted by a committee under the procedure of the American Engineering Standards Committee. The general interest aroused during the preliminary work on this code and the development of the accelerometer mentioned above have led to general adoption of more effective means of controlling the condition of motor-car brakes.

While brakes are one element in determining what speed a vehicle may safely maintain under any particular condition of traffic, there are other factors equally important, such as condition of the highway surface, as well as traffic conditions themselves. The Bureau of Standards has made a study of these factors and incorporated the findings into a single statement "Safe speed is that from which a vehicle can always be stopped within the clear course ahead," where clear course is defined as that portion of the highway

which the driver can know is unobstructed and can not become obstructed by any person or other vehicle within the ordinary right-of-way rules, in such a way as to interfere with his progress.

It has been suggested that this general principle can be made the basis for more effective legislation than now exists regarding vehicle speed.

A brief study has been made of the theoretical safe traffic capacity of highways as affected by brake ability and average speed of traffic. The results of some of these calculations have been published and others are available for such use as may arise.

Closely related to brake performance is that of the car under application of the brakes. The dangerous action of a vehicle sometimes known as pivoting under action of the brakes on slippery roads has long been something of a mechanical mystery. Some time ago an analysis was made of the causes of this behavior by the use of models, and it was found that there is a simple mechanical explanation for the phenomenon. It was shown that, contrary to previous generally accepted belief, when on a slippery surface the rear wheels of a vehicle are locked it must necessarily reverse its direction unless the tendency to do so is skillfully controlled by proper steering. Locking of the front wheels, on the contrary, while it prevents steering of the vehicle, does not have this effect, but under these conditions a vehicle will proceed straight ahead. A knowledge of these facts appears to be of utmost importance in the design and adjustment of two and four wheel brakes and it may, perhaps, influence other matters of highway and traffic control.

**Motor Vehicle Headlighting.**—Automotive headlighting and its relation to highway illumination has been a subject of much recent discussion. While many of the States have fairly adequate laws for the licensing of headlighting equipments and for their proper adjustment and use, there are only a few localities where anything like satisfactory headlighting conditions exist. This fact raises the question whether existing laws are adequate in themselves or whether the fault is in enforcement alone. Recently the Bureau of Standards in co-operation with the Illuminating Engineering Society and the Society of Automotive Engineers has been making a study of the safety and effectiveness of different headlight illumination patterns. For this purpose two special adjustable headlight sets each consisting of four lamps are available for use on different cars. Some work has already been done in an attempt to determine independently what type of lighting is safest for the driver when no other cars are approaching, and what type is safest for both when cars are approaching. With modern depressible lighting systems it is conceivable that both these conditions of maximum safety can be realized. To make this possible it is necessary to know first

what beam patterns will afford maximum safety under each of the above conditions, rather than what is the best simple compromise between them.

The bureau has been co-operating with manufacturers of headlamp and headlighting devices and with the Commissioners of Motor Vehicle Administrators of a number of States, particularly on the Pacific coast and with the States comprising the Eastern Conference of Motor Vehicle Administrators. Tests on some 40 devices have been made for the State of Oregon, and numerous tests have also been carried out for the Director of Traffic of the District of Columbia.

On this subject of headlights the bureau has issued a circular entitled "Motor Vehicle Headlighting," Circular No. 276, and a chart, "Adjust Your Headlights," Miscellaneous Publication No. 68, which are widely used.

**Tests of Signals.**—As to signal lights, a sectional committee, working under the auspices of the American Engineering Standards Committee and sponsored by the American Association of State Highway Officials, the National Safety Council, and the Bureau of Standards, has agreed upon specifications for the use of colors, and this has already resulted in pretty general adoption of uniform practice in the use of red, green, and yellow luminous signals for traffic control.

A series of tests has been made on the visibility of red, yellow, green, and blue traffic signal glasses under daylight conditions. It was found that color traffic signals under daylight with the sun shining on the signals are clearly distinguishable by the average observer at a distance of 1,200 ft. from the signal if there is behind the signal a light having a beam candlepower of approximately the following values for the four colors: Red, 1,400; green, 2,600; yellow, 3,800; and blue, 9,300. It was found that a 15-watt lamp in a 4 or 5 in. parabolic reflector will be satisfactory to use as a source of light for such signal glasses and that with a lamp of that intensity the colors will be clearly distinguishable at a distance of 1200 ft. even though the sun is shining directly on the signals.

**Visibility of License Plates.**—Experiments have been conducted on the visibility of the letters and figures on automobile license plates. It is found that there is, of course, great difference in the intensity of illumination on rear license plates as produced by tail lamps ordinarily supplied on automobiles. There is also considerable difficulty due to the fact that the design of the letters and figures themselves as used on the license plates of a number of States is not the best in many instances. Certain figures are difficult to distinguish even under daylight conditions. It is found, in general, however, that dark letters and figures on a light background are more readily visible and legible than are light-colored letters and

figures on a dark background. In other words, letters and figures in black, dark green, or maroon on yellow, white, or buff backgrounds are more easily distinguished than white, yellow, or buff figures on black, green, dark blue, or dark red backgrounds. It would appear desirable to suggest to commissioners of motor vehicles in the various States that this fact be kept in mind in selecting the combination of colors for the annual issue of license plates. These principles apply also to highway markings.

An investigation carried out at the request of the Director of Traffic for the District of Columbia on a small number of rear signal lamps commonly called "stop signals" shows a rather confused state of supply for these devices. More work should be done in a study of the design of the reflectors and glasses used for such rear signal devices.

**Standards.**—In conclusion, I would like to refer again to the importance of the work of national organizations engaged in promulgating standards, such as the American Engineering Standards Committee and the Federal Specifications Board, which last is doing so much to unify requirements for Government purchases. If the service to be rendered is the same, there is no reason why the requirements for road materials and other equipment in one State should differ from those in another. Uniformity in purchase requirements does much to insure the best material at the lowest price. In this movement I believe the bureau has played an important part, because it has oftentimes assisted in determining what the best material really is for a given purpose.

In what precedes I trust I have left with you the impression that the laboratory is essential to the highway as an aid in working out many of the highly complex problems confronting its operation and maintenance. The real test, however, of the adequacy of the laboratory investigation, is service in or on the highway of the material, machine or practice recommended by the laboratory. If, in this paper, you find I have unduly emphasized the role of the Bureau of Standards, you will appreciate that I have limited my remarks to that laboratory and those problems with which I am best acquainted.

**Road Construction in Quebec.**—The road program of the Province of Quebec for this year provides for the construction of the balance of the main truck highway system totalling about 230 miles; 400 miles of county and local roads; permanent resurfacing of 125 miles of Provincial and regional highways and 25 miles of county and local roads improvements. The budget for the present year amounts to \$6,500,000.

# How Three States Specify on Woven Wire Guard Rail

Some Late Highway Department Specifications for Woven Wire Guard Rail Received Too Late for Incorporation in the 1927 Issue of Our Road & Street Catalog and Data Book

Woven wire guard rail is a widely used safety measure on state highways throughout the country. Three states whose road building program is ever of some magnitude, whose specifications on various elements of their work are generally considered up to date, and whose use of such guard rail is sufficiently wide to have given them an opportunity to develop worth while specifications, have just submitted their specifications for publication in this journal. Unfortunately these specifications were received too late for incorporation, too, in the 1927 edition of Road & Street Catalog and Data Book.

It is but natural that some similarity is to be found between the various specifications, since a number of years of use of this type of highway guard would normally weed out faulty design and surely bring out the main features that lead to stability and economy. Take, for instance, the manufacture of the mesh itself. Here the practice is to call for a width of 24 in., the mesh to be made of No. 6 W. & M. gauge galvanized steel wire woven with a 2-in. square mesh. There is additional similarity in other provisions. The follow-

ing specifications will bear considerable study.

**Illinois Specifications.**—The state of Illinois has specified as follows, in Specification 18-D, Wire Guard Fence, Type D:

**1. Description.** Wire guard fence shall consist of a wire link fabric supported by wood posts, constructed where specified on the plans and in accordance with these specifications.

## Materials

**2. Posts.** The posts shall meet with the requirements of the Standard Specifications, Specification XVIII, Section 18-2, Wood Guard Rail.

**3. Paint.** The paint used shall meet with the requirements of Specification XXXIII, Section 33-8, White Lead Paint.

**4. Wire Link Fabric.** The wire link mesh shall be manufactured from standard galvanized steel wire, of No. 6, W. & M. gauge, woven in a mesh of two (2) in. squares. It shall be given one (1) coat of white paint meeting with the requirements of these specifications. The width shall be twenty-four (24) in.

The top and bottom edges of the fabric shall have the wire turned over or "knuckled." It shall be furnished in continuous rolls of one hundred (100) ft. wrapped in burlap.

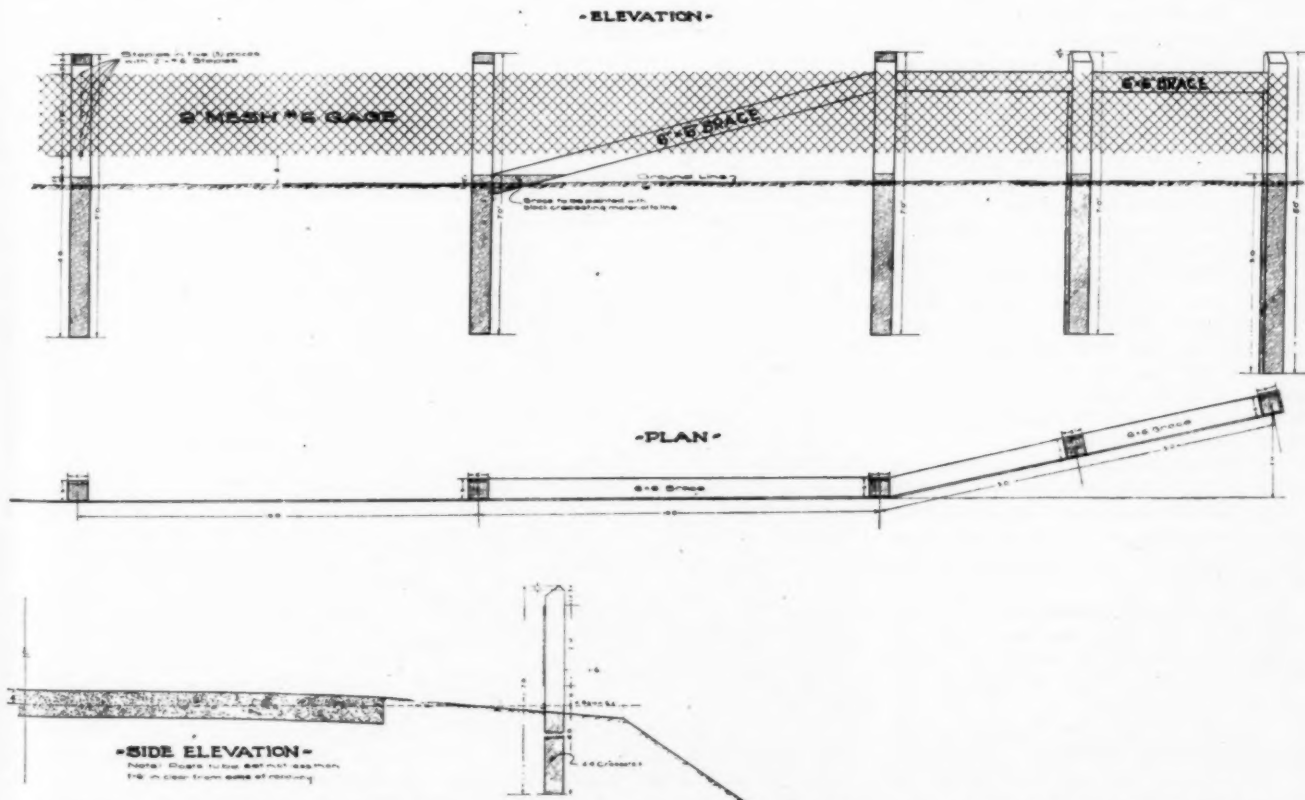
## Construction

**5.** The guard fence shall be constructed in accordance with Standard Plan No. 1185.

The posts shall be set vertically to the full depth shown on the plans, and accurately aligned. They shall be set ten (10) feet apart except on curves where they shall be set eight (8) feet apart. In backfilling post holes, care shall be taken that only suitable material is used and that it is tamped thoroughly.

The fabric shall be attached to the side of the post facing the road, using three (3) one and one-half (1½) inch galvanized staples in each post. On curves, strips of galvanized metal, six (6) inches wide, twenty-four (24) gauge, shall be securely wired to the top and bottom of the fabric. These strips shall be given two coats of white paint.

Before the fabric is attached, the



Drawing Taken from the Florida Specifications, Showing a Method of Construction That Typifies the Methods Used by Most States

upper two (2) feet eight (8) inches of the posts shall be given two coats of white paint and the six (6) inches above the ground line two coats of black paint.

After erection, such portions of the original paint coat on the wire fabric as have become scratched or damaged shall be given an additional coat of white paint. For priming coat on exposed wood surfaces, the paint may be thinned to facilitate penetration by the addition of turpentine, the quantity of which shall not exceed one-half ( $\frac{1}{2}$ ) pint per gallon of mixed paint. All paint coats shall be brushed out thoroughly.

#### Basis of Payment

6. This work, except metal strips, shall be paid for at the contract unit price per linear foot for "Wire Guard Fence," complete in place, including all materials, equipment, tools, labor, and work incidental thereto. The galvanized metal strips shall be paid for at the contract price per linear foot complete in place.

**Florida Specifications.**—The state of Florida, in Section 68, Woven Wire Guard Fence, of the state specifications, calls for the following:

68.1. **Description:** This item shall consist of chain or wire link mesh supported by wooden posts as indicated on plans or directed by the Engineer and in accordance with these Specifications.

#### Materials

68.2. **Posts:** The wooden posts shall conform to the requirements for "Posts," Paragraph 67.2, Section 67 of these Specifications.

68.3. **Chain Link Mesh:** The mesh shall be manufactured of standard galvanized steel or iron wire or equal, of full No. 6 W. & M. gauge, woven in a mesh of two (2) inch square. The width of the completed fabric to be twenty-four (24) inch and to be galvanized after weaving and painted white.

Both top and bottom edges of fabric to have wire turned over or what is termed as knuckled.

The fabric is to be furnished, crated in 100 foot rolls of continuous length.

Fabric shall be made of a good grade of Basic Open Hearth Steel Wire.

68.4. **Zinc Coating.** The zinc used for coating shall be pure virgin spelter conforming to A. S. T. M. Standard Specifications B-6.

Fabric shall be galvanized after weaving and the weight of zinc coating per square foot of wire surface shall be not less than 0.8 oz. and shall withstand a minimum of four (4) one minute dips by the Preece Test.

The quality of galvanizing shall be such that the zinc coating shall not crack, peel or flake during ordinary handling in shipment or erection of the guard.

68.5. **Testing of Zinc Coating:** Zinc coating shall be tested for quantity by Stripping Test and for uniformity by the Preece Test.

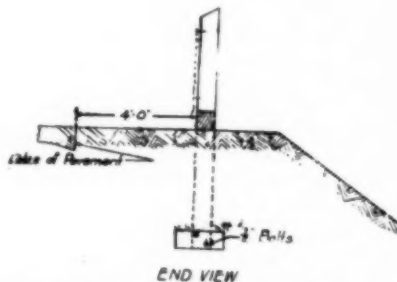
The stripping test will be conducted

on one (1) square foot of fabric selected at any point in the width of the fabric from the end of the roll exclusive of the knuckled portion and the results will be reported in ounces of zinc per square foot of wire surface. The test will be performed by the Sulphuric Acid Stripping method as described in the A. S. T. M. Standard Methods A-90. By means of the following formula the wire surface area in one square foot of fabric can be calculated to facilitate conversion to ounces of zinc per square foot of wire surface.

$0.516 \times W$ —Square feet of wire surface of No. 6 Wire.

W in the above formula is the weight of wire in one (1) square foot of fabric after stripping.

By weighing the sample before stripping and after stripping, weight of coating can be determined.



A Construction Detail Taken From the Illinois Specifications Showing the Wooden Anchor Used on the Bottom of the End Posts

The Preece Test shall be conducted on one (1) square foot of fabric selected at any point in the width of the fence from the end of the roll, exclusive of the knuckled portion and the test shall be made as described in the A. S. T. M. Standard Methods, A-90-24.

68.6. **Paint:** Tops of post above creosoted part, and all joints when dry, shall be given three (3) coats of paint composed of from sixty-five (65) to seventy (70) per cent, by weight, of pigment in paste form, and from thirty (30) to thirty-five (35) per cent of vehicle, or sixty (60) to sixty-five (65) per cent, by weight, of dry pigment.

The pigment shall be composed of not less than sixty-five (65) per cent of pure white lead, and not less than twenty (20) per cent of pure zinc white, all finely ground. Not more than fifteen (15) per cent of pure raw linseed oil and sufficient first quality Japan, or other approved drier, shall be used to cause the applied paint to dry in approximately three (3) days, but in no case shall the drier exceed ten (10) per cent.

68.7. **Cresote Oil for Brush Treatment:**

1. The oil shall be a pure distillate of Coal-gas tar or Coke-oven tar.

2. It shall be fluid at 15°C. and crystal free at 38°C.

3. It shall not contain more than 1 per cent of water.

4. It shall not contain more than 0.5 per cent of matter insoluble in benzol.

5. The specific gravity of the oil at 38°C. compared with water at 15.5°C. shall not be less than 1.06.

6. The distillate based on water-free oil shall be within the following limits:

Up to 210°C. not more than 1 per cent.

Up to 235°C. not more than 10 per cent.

Up to 355°C. not less than 65 per cent.

7. The residue above 355°C. if it exceeds 10 per cent shall have a float test of not more than 50 seconds at 70°C.

8. The oil shall yield not more than 2 per cent coke residue.

68.8. **Construction Methods:** The posts shall first be thoroughly coated with three (3) heavy coats of oil of the kind specified herein, for a distance of four and one-half ( $4\frac{1}{2}$ ) feet at their butt ends. They shall then be set vertically to the full depth shown on the plans and accurately lined and relined until final acceptance of project. The post-holes shall then be backfilled, using great care to see that only suitable material is used in the backfill, and that it is thoroughly tamped. The tops of the posts shall be sloped on top and sawed to exact grade after the tamping of the backfill is finished. End posts shall be extra length and braced as shown on plans. The mesh shall be secured to post on side of posts facing the road, with five (5) two (2) inch No. 9 staples in each post, one staple at top of fabric, one at bottom and three (3) evenly spaced between top and bottom staples. The bottom edge of the mesh to be twelve (12) inches above ground line or as shown on the plans.

**Note:**—Intermediate posts are to be creosoted with block creosote for a distance of 4 feet from the butt end, and end posts 5 feet from the butt end. The entire post above treated portion, including top, to be given 3 coats of paint as specified. All posts and braces to be cut from sound heart cedar, yellow locust, white oak, post oak, chestnut, long leaf yellow pine, juniper, or red-heart cypress, and of the dimensions shown. End posts to be 8 feet in length.

Posts to be dressed on all four sides. Size 6 in. x 6 in. after dressing, in accordance with Paragraph 68 of the State's Standard Specifications.

68.9. **Basis of Payment:** This item will be paid for at the contract unit price per linear foot for "Woven Wire Guard Fence," which price shall be full compensation for furnishing, preparing, hauling and erecting all materials, and for all labor, equipment, tools and incidentals necessary to complete the work.

**Ohio Practice.**—Information just now available from Ohio indicates that this state, too, requires mesh of No. 6 W. & M. gauge galvanized steel wire, woven in 24 in. widths into 2 in. square mesh. Galvanizing is at a minimum rate of 120 lb. per ton. Posts must be of straight sound chestnut, white oak, yellow locust, white cedar, or red cedar, 6 in. minimum diameter, and have a

minimum length of 6 ft. 6 in. These posts are creosoted by dipping the lower 4 ft. 4 in. All exposed surfaces not galvanized are given three coats of white lead and linseed oil paint. All surfaces in contact and not galvanized are given one coat of the same paint before erection. All iron and steel is galvanized after fabrication. Posts are set 10 ft. apart and the tops are then trimmed with a 1 in. camber so that 3 ft. projects above ground. The mesh is attached to the posts, with the upper edge 2 in. below the top of the posts, by means of 2 in. staples. End posts are set in 1:2½:4 concrete, about 2½ cu. ft. to the post, so that at least 4 in. of concrete surrounds the embedded post. Mesh is bent half around this end post and stapled at first point of contact and again on the opposite side. The end post is braced by a diagonal 4 in. by 4 in. timber brace from 3 in. below its top to the bottom of the exposed portion of the adjoining post. The posts are notched 1 in. to receive this brace, which is nailed at each end by four 5 in. spikes, 2 in the top (and bottom) and 2 in the sides. This guard rail, known as Type E, is specified in detail in Item R-4 in the department's General Specifications.

### Double Batch Hopper Loaders

Special double hopper Haiss loaders are being used with 2-batch trucks by a number of Chicago contractors for supplying mixers and batching at stock pile as near the work as possible. A truck gets two batches of stone, then the cement and then the two batches of sand. The value claimed for the double

batch loader is the faster dispatching of the truck.

The double loader does not take the place of two loaders, one in stone and one in sand. It makes two batches of stone, or two batches of sand, available at one time for the double batch truck.

The loaders are Standard Haiss Loaders, excepting that the creeper mounting is 15 in. longer and the front chassis construction is heavier, to carry the double load, and the hopper has a dividing plate and two outlet gates to discharge the two batches independently.

The hoppers are of the Haiss Precision type, with micrometer capacity adjustment and can be provided with strike-off and interlock. The maximum capacity, struck-off, is two 25 cu. ft. batches, and is adjustable to two 18 cu. ft. batches. By a single substitution in the upper truncated pyramid section and the bolting in place in the lower box section of some reducing plates, the capacity is changed for sand to two batches of 11 to 16 cu. ft. each.

The hopper and its supporting platform can be lowered by a winch on the elevator, and the elevator itself lowered to an overhead clearance of 10 ft. 6 in., in less than ten minutes. This means that the loader can be carried on a trailer under a viaduct with 12 ft. 6 in. or more clearance.

The discharge chutes of the hopper have a minimum discharge height of 7 ft. 6 in., and a reach from the bumper of the loader of 4 ft. 10 in. The clearance under the hopper supporting platform is 7 ft. 10 in. clean back to the bumper.

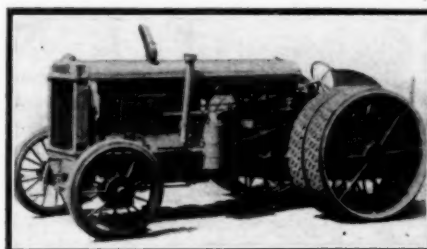
The reach and clearance make it

possible to load with compartments over the side or the end as desired. As is the case with the standard Haiss loader with precision hopper, all of the controls are grouped at the operator's platform.

### New Large Tractor Has Rubber Treads

The new Huber Super Four industrial tractor is said to be the heaviest wheel tractor yet to be equipped with rubber treads. It has been designed for freighting, road building, road maintenance and general industrial service where the work to be done and the loads to be handled are beyond the capacity of the smaller industrial tractors.

It is made in three sizes that deliver



The New Huber Industrial Tractor

22, 30 and 40 h. p., respectively, at the draw bar (S. A. E. rating). It is provided with low speed for heavy work and a high speed to make it suitable for long distance freighting service. Transmission is enclosed and runs in oil and it is equipped throughout with roller bearings. Power take-off and belt pulley equipment makes it available for all classes of belt and draw bar work.

It is made by the Huber Manufacturing Co., Marion, O., manufacturers of road rollers and road tractors.

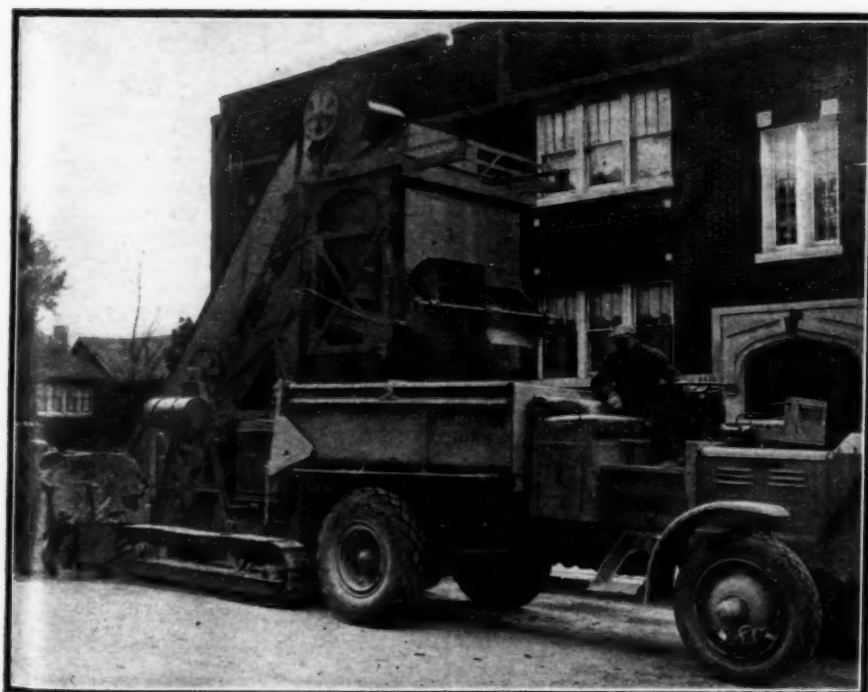
### Third Unit St. Louis Street Lighting Contract Awarded

The third unit of St. Louis' \$8,000,000 lighting program was awarded on July 1 by the City Board of Public Service to E. Locke Tarleton, local contractor. All the electrical equipment for this unit of the improvement, the same as for the first and second units, will be furnished by the Westinghouse Electric & Manufacturing Co.

The contract awarded today involves approximately \$1,000,000 and calls for the installation of 4,355 lighting units and accessory equipment.

The first contract consisted of nearly 10,000 units and the second about 3,300 units and all accessory equipment. To expedite the manufacture of the lighting units, the Westinghouse Co. established a plant in St. Louis early this year.

Prior to the present contract, the Westinghouse Co. had supplied, in addition to the lighting units, nearly 15,000 poles, three automatic substations and more than 850 miles of steel armored cable. All poles are of the hollowspun granite type.



Double Hopper Haiss Loader on Job of R. R. Anderson Co.

## New Selden Roadmaster Truck

The new Roadmaster Model 47, the latest addition to the line of the Selden Truck Corporation, Rochester, N. Y., is stated to embody many improvements worked out by Selden engineers after very extensive tests and experiments.

While the same 6-cylinder 72 H. P. Continental motor is being used because of its remarkable performance in actual service during the past two years, also the same bevel gear rear axle, many other changes have been incorporated such as deeper frame (7-in. frames are now standard), larger castings, shackles, and brackets and heavier springs. Air cleaners and oil filters are also standard equipment on the new Roadmaster.

One important feature which has been given special attention by Selden engineers is the brakes. The new Roadmaster embraces an entirely new service brake hookup which brings all four shoes into operation through the service brake pedal with the aid of the B. K. Vacuum booster brake. In addition to this, a propeller shaft brake is furnished if desired, which consists of a steel disc located back of the center bearing and is used as a hand brake. Only light pressure is necessary to bring this brake into positive action.

The DeLuxe cab is another advanced step—the comfort and convenience of the driver being the chief considerations. The deep seat cushion with bus type springs, combined with the steering wheel angle provide an extremely comfortable sitting posture. The remote control type of door opener and window regulator are of the latest bus design. Large door openings and narrow corner posts provide unobstructed vision for the driver which is a big factor of safety.

All instruments, including dash type of motometer, gasoline gauge, oil pressure gauge, speedometer and ammeter, are grouped in a center panel under glass with concealed lighting. Ignition and lighting switch are located

on a bracket on the steering column. Automatic windshield wiper and rear view mirror are standard equipment with this cab.

Dual rear pneumatic tires and the Ryan Ileo flat lights, conceded by engineers to be the best lights obtainable, are also part of the regular equipment.

## Liquidated Damage and Bonus Clauses in Connecticut State Highway Contract

The latest revision of the specifications and contract of the State Highway Department of Connecticut contains clauses relating to liquidated damages and bonus and also a time charge. The following is an extract from the Connecticut document:

"Failure to Complete Work on Time. Time is an essential element of the contract and as the prosecution of the work will incommode the public, obstruct traffic and interfere with business, it is important that the work be pressed vigorously to completion. Also the cost to the Department of the administration of the contract, including engineering, inspection and supervision will be increased or decreased as the time occupied in the work is lengthened or shortened. Therefore, either a liquidated damage and bonus charge or a time charge will be made against the Contractor in accordance with one of the following provisions:

(a) Liquidated Damages and Bonus. For each working day that any work shall remain uncompleted after the time specified for the completion of the work provided for in these specifications, the proposal and contract, the sum per day given in the following schedule, unless otherwise specified in the proposal form, shall be deducted by the Engineer from money due the Contractor, not as a penalty but as liquidated damages. Provided, however, that an allowance may be made by the Commissioner, at his discretion, extending the period specified for the completion of said work, for causes over which the Contractor has no control and which must delay the completion of said work, and in such case the Contractor shall become liable for said liquidated damages for delays commencing from the date on which said extended period shall expire.

Amount of Contract	Per Day
\$5,000 or less.....	\$10.00
More than \$5,000 and less than \$10,000.....	15.00
More than \$10,000 and less than \$25,000.....	20.00
More than \$25,000 and less than \$50,000.....	25.00
More than \$50,000 and less than \$100,000.....	30.00
More than \$100,000 and less than \$250,000.....	40.00
More than \$250,000.....	50.00

In case the Contractor shall complete the con-

tract in a less number of days than above specified, he shall receive the sum given in the above schedule as a bonus for each day that the contract is finished within that time.

(b) Time Charge. A time charge of the amount stated in the proposal, will be made against the Contractor for each and every day (Sundays excluded) that the work is in progress and the amount of it will be deducted from the monthly and final payments as these are made. This charge will be commenced on the day the work is started and continue until the completion of the work. Each bidder should include in his estimate of the cost of the work a sum equal to the amount derived by multiplying said time charge by the number of days within which he estimates he can complete the work. This sum shall not appear as a separate item of the bid, but should be distributed among the various items on which prices are asked on the proposal form. The time charge will be suspended during the period of any delay that may be caused by the Department, either through change of plan or through ordering suspension of the work for any reason other than failure on the part of the Contractor to comply with the Specifications.

If any delay is caused to the Contractor by specific orders of the Engineer to stop the work (for reasons other than failure on the part of the Contractor to comply with the requirements of the Specifications), or by failure of the Engineer to provide necessary instructions for carrying on the work, or to provide necessary right-of-way, such delay will entitle the Contractor to an equivalent extension of time, and the suspension of the time charge only during such an extension of time. When extra or additional work is ordered by the Engineer, the Contractor will be allowed a suspension of the time charge equal to one day for each five hundred (\$500) dollars of the cost of such additional work.

Note: Unless specific instructions to the contrary are given in the proposal form, the liquidated damages and bonus clause as described under (a) above shall apply in the construction of all projects."

## \$13,880,000 of Road Bonds Voted in Iowa.—The following counties in Iowa voted recently to issue bonds for road construction:

County	Amount
Franklin .....	\$ 740,000
Monona .....	1,000,000
Washington .....	1,000,000
Woodbury .....	700,000
Jones .....	1,200,000
Monroe .....	600,000
Lucas .....	530,000
Lee .....	1,000,000
Harrison .....	1,000,000
Plymouth .....	1,200,000
Butler .....	1,200,000
Winneschiek .....	1,200,000
Buchanan .....	1,000,000
Bremer .....	900,000
Montgomery .....	600,000
Total .....	\$13,880,000

**American Engineering Council Studying Traffic Conditions.**—Nearly 100 committees of the American Engineering council are conducting a survey of traffic conditions in the principal cities of the country. The object of this undertaking is to determine the best practices as to signs, signals and markings as a means of facilitating traffic and increasing safety on the streets of the cities of the United States.

**\$40,000,000 Available for State Highways in Ohio.**—Ohio will have approximately \$40,000,000 for road improvement during the next year and a half, according to a resume of the state highway situation, which was submitted by Executive Secretary W. A. Alsdorf of the Ohio Good Roads Federation at a meeting of the board of trustees of the federation.



New Selden Roadmaster 6-Cylinder, 3 Ton Speed Truck

## Aggregates for Highway Construction

Material Used in the Building of Roads in Ohio Discussed in Paper Presented at Annual Convention of National Sand and Gravel Association

By A. S. REA

Engineer of Tests, Ohio Department of Highways and Public Works

In contrast to the policy followed by a number of states, Ohio has not limited her highway program to one or two types of construction. We have perhaps more diversity of types than any state in the Union. Then, too, so far as material specifications are concerned the policy has been to show no discrimination for one class of material for any particular type of construction. For example, in concrete pavements we are using three classes of coarse aggregate: gravel, limestone, and blast furnace slag. While we have more miles of concrete pavements and concrete bases with gravel as the aggregate than any other type of coarse aggregate, we recognize that fairly satisfactory concrete can be obtained with other classes of mineral aggregate.

**Term "Aggregate" Used in General Sense.**—I wish to say in the beginning, too, that when we speak of mineral aggregates in highway engineering our interpretation of the word "aggregate" is in the more general sense and includes gravel for gravel roads, stone and slag for macadam, etc., as well as these materials for concrete. For example: our specifications state that the coarse aggregate for macadam base shall meet a certain specification and be of a certain size; all of the other state highway departments follow the same plan so far as I know. This interpretation does not agree with tentative definition of the term aggregate as proposed by a committee of the American Society for Testing Materials, which is as follows: "Designated inert material which when bound together in an agglomerated mass by a matrix forms concrete, mortar, plaster, etc." It will be readily seen that this definition does not contemplate the use of the term aggregate for gravel or stone for such use as gravel road or stone macadam. It should be remembered, however, that the definition referred to is only a tentative one, and since several revisions have already been made in the wording of the definition, it does not necessarily represent the last word. I think, without doubt, most highway engineers will continue to use the word in its more comprehensive interpretation.

**Percentage of Mineral Aggregate.**—In every type of highway construction, whether it be a hard-surfaced pave-

ment, so-called permanent pavements, or for traffic-bound gravel roads, so-called stage construction, as well as for all classes of highway structures, mineral aggregates of one type or another are used to some extent. I wonder if the producers of aggregates themselves realize the extent to which their product plays in the vast highway program. It is, I think, very conservatively estimated that of the total mass of materials incorporated in our highways that not less than 90 per cent of the total volume is composed of mineral aggregates. It is, of course, not a difficult thing to calculate this for any given type of construction. I have done this for a number of types of pavement, and roughly estimated the percentage for the state highway system in Ohio. This varies from approximately 57 per cent by volume of mineral aggregates in a 3½-in. brick pavement with a 1-in. sand cushion on a 5½-in. concrete base to 100 per cent for a gravel road or a waterbound macadam road.

The per cent by volume of mineral aggregate in a concrete pavement 1-2-3 mix, disregarding the water, would be 5/6 or 83 1/3 per cent. It can be readily seen, therefore, that the tonnage of aggregates incorporated in our highway system is enormous.

**Types of Highway in Ohio.**—Referring now to the state highways in Ohio, we have 88 counties in the state. The state is divided into eleven divisions, each division having the same number of counties—eight. Each division is in charge of a division engineer, who has his headquarters in his division, and is responsible for all construction and maintenance work within his division. At the present time the state highway system, having a total of approximately 11,000 miles, has over 9,000 miles improved or under contract. Up to January 1, 1927, 8,800 miles had been actually completed, as follows:

	Miles
Waterbound macadam .....	1,267
Bituminous macadam .....	1,259
Portland cement concrete .....	1,543
Brick .....	1,339
Bituminous concrete .....	239
Sheet asphalt .....	33
Rock asphalt .....	143
Traffic bound .....	2,967
Earth .....	40
<b>Total .....</b>	<b>8,830</b>

Roughly then the construction completed is composed of 2/3 pavement and 1/3 traffic bound, chiefly gravel.

The pavement is divided approximately one-fourth water-bound macadam, one-fourth bituminous macadam, one-fourth concrete, one-fourth brick.

In general, the state of Ohio is well provided with high-way materials, particularly with respect to mineral aggregates. It is much more fortunate in this regard than many other states.

The western half of the state is dominantly a limestone area, and the eastern half is dominantly a sandstone and shale area. This is true provided the unconsolidated or mantel rock is lifted

from the bed rock. North and west of a line passing through Lisbon, Canton, Millers-Grove, Chillicothe, Bainbridge and Ripley (which line in a general way parallels the Ohio River), this mantel rock consists of gravel, sand or clay or a mixture of all three, resting directly on the hard, fresh bed rock. South and east of the line, on the other hand, the mantel rock of sand, clay and the like, grades gradually into the bed rock beneath. The unconsolidated rock of the former area was brought in and deposited by the great ice sheets which covered much of northern North America. That of the latter area is the residue formed by the disintegration of the bed rock and the line between is the glacial boundary.

In many places within the glaciated area the waters formed by melting of the ice sheet assorted the glacial material and deposited it in beds of gravel, sand and clay. This was so commonly the case that most counties within this area have more or less widely distributed beds of gravel and sand which may be utilized when properly prepared for highway construction.

**Composition of Gravels.**—In a general way the gravels found in the western half of the state are composed largely of limestone pebbles with certain of the glacial gravels containing a considerable per cent of igneous rock, such as granite, trap and quartz. The gravels found in the eastern part of the state and also the Ohio River gravels contain more or less sandstone, some of which is very hard, together with quartz and granite.

With reference to the quality of the gravel and sand found in the state it may be said that as a rule it is very satisfactory for either concrete construction or for traffic-bound gravel construction.

Enormous quantities of bank gravel and river gravel, including the Ohio River gravel, have been and are now being used for highway construction. Sand screened from such gravels, as well as sand from Lake Erie on the north, has been extensively used for concrete. The lake sand is also widely used for sheet asphalt and bituminous concrete construction.

As previously indicated, slag is included among the mineral aggregates used for highway construction. Slag, which is used in highway work, is obtained as a by-product of the blast furnace in the production of iron. In certain sections of the state where little or no gravel or stone is found locally, crushed slag has been used rather extensively in both macadam and concrete.

**Uses of Aggregates.**—Just a word about the various grades and classes of mineral aggregates used in highway construction with some reference to the types of construction in which they are used.

The Ohio specifications during the past season covered 23 grades or classes of mineral aggregates (9 classes of

fine, 14 classes of coarse). A number of these, however, are really obsolete, in that they are little if ever used, except possibly in a few special cases. For example, the specifications still carry the requirements for grout sand for brick pavement. This type of filler has practically been discontinued in favor of bituminous filler. A number of the classes of aggregates will be eliminated in the 1927 specifications.

In the nine classes of fine aggregate were included the requirement for two grades of concrete sand, designed as Grade A and Grade B, the former specified for concrete pavements and the latter for concrete bases. Also in addition to the sand for grout the specifications covered sand for cushion under brick sand for filler to be used with tar or asphalt as a mastic, a very coarse sand for covering as a surface treatment in asphaltic concrete, screenings for macadam, and also an asphalt sand for sheet asphalt and bituminous concrete construction. It is, of course, understood that a difference of quality is not necessarily involved in specifying such a large number of grades or classes. The same producer can and does furnish without difficulty a number of grades. It is simply a matter of properly screening in many cases, as represented, for instance, in the production of a concrete sand and a mortar sand. Certain types of construction require particular qualifications as to grading. A first-class concrete sand would be a very poor asphalt sand, and vice versa.

The material specifications for coarse aggregate cover 14 different classifications, including four grades of limestone, three grades of blast furnace slag, and four classes of gravel. You will note that a distinction has been made between "grades" and "classes." In regard to both limestone and slag the classifications are based upon quality of the aggregate. For instance, a higher resistance to wear, higher hardness and toughness are specified for Grade A limestone than any of the other grades. In the same manner Grade A slag must be of a better quality than Grades B or C. In the case of gravel, on the other hand, while there are four different classifications, there are but two grades so far as quality alone is concerned. Grade A gravel with a per cent of wear of 12 specified in the modified Deval test is specified for concrete pavements. Grade B gravel with a loss of 25 per cent is permitted for concrete foundations not subject to wear. The other two classes of gravel, namely: Gravel "C" and Gravel "D" are for Gravel Base Course and gravel for traffic-bound construction respectively. I might say in this connection that the traffic-bound gravel roads have proven so popular and successful in this state that at a recent meeting of the engineers it was voted to discontinue the old type of water bound gravel; hence Gravel "C" will be

eliminated from the revised specifications.

**Construction of Gravel Roads.**—In conclusion, I wish to say a word about the work which has been done in this state in the last two or three years in the construction of gravel roads.

Up to Jan. 1, 1925, we had but 600 miles of gravel road under state maintenance. Up to Jan. 1, 1926, there had been completed 1,608 miles of traffic-bound construction. During the past year 1,359 additional miles were completed. It is expected that between 1,600 and 1,700 miles will be added during the year 1927.

To some of those from other states it might be of interest to know something of the specifications for the class of gravel used for this purpose.



Loading directly into two trucks from the three scrapers as told above

The specifications for Gravel "D" state that the gravel shall be composed of hard, durable particles of stone thoroughly clean (before crushing). The gravel shall be crushed so that the portion retained on the  $\frac{1}{4}$ -in. screen shall contain not less than 40 per cent of angular pieces.

Per cent of wear not over 12 per cent.

Grading—it is required that not less than 95 per cent shall pass a  $\frac{3}{4}$ -in. ring—25 to 75 per cent pass a  $\frac{1}{2}$ -in.—15 to 35 per cent pass a  $\frac{1}{4}$ -in. and not over 15 per cent pass a No. 10 sieve.

This type of construction, as many of you know, has proven extremely popular in certain sections of the state. It is granted that it will be many years before all of the roads on the state system can be hard-surfaced. In many localities of the state the construction of high-priced pavements is economically unjustified.

The construction of the gravel roads has enabled some of the poorer counties of the state to break the mud quarantine and has given them splendid all-year serviceable roads in these communities, at a cost of approximately \$3,000 per mile (including the grading).

## Loading Two Trucks at a Time with Scrapers

John Frantz, contractor, of Sidney, O., disposes of his dirt from the subgrade as shown in the picture. The grading is done with three Miami scrapers, each pulled with a Fordson tractor. When grading streets in his city, he erects the loading platform shown, and the scrapers bring the dirt up one

side, dump at the top, and pull down on the other side to return for the next cut. The structure provides two openings, so that two Ford 1-ton trucks drive beneath the ramp, as shown in the picture. The haul was about  $\frac{1}{2}$  mile on the work shown, and the route to the dump took the trucks through the city and over a freight yard, where the trucks were frequently delayed by switching on the railroad. On one operation the organization thus excavated and moved 424 cu. yd. of dirt from an important street in 20 hours' time under the above conditions.

**Georgia Discontinues Use of Bid Bonds.**—The Georgia Highway Department is one of the latest construction agencies to eliminate the use of bid bonds in connection with proposals for state highway work. Certified bidding checks are now being required with all bids.

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## Snow Removal in Michigan

Results Obtained During the Winter of 1926-7

The snow removal program in Michigan during the past winter covered 5,704.7 miles of road. The cost of the program from Oct. 1 to Dec. 31, 1926, was \$81,547; from Jan. 1 to April 1, 1927, the cost was \$220,927. This gives a total cost of \$302,474 or \$53.02 per mile of road on the program. Some interesting information on this snow removal work is given by V. R. Burton, Engineer of Research and Statistics of the Michigan State Highway Department in Michigan Roads and Pavements, from which the notes following are taken.

**Snowfall Under Normal.**—The amount of snowfall during the past winter was considerably under normal throughout most of the state, with several notable exceptions. Deer Park shows the highest snowfall, with 245 in.—being almost twice the amount of snowfall shown at any other station in the state. At Calumet this year the snowfall was about 22 in. below normal, while a few miles away, at Houghton, the snowfall was about 12 in. above normal, the snowfall at Houghton being the heaviest of any station reported which was on the snow removal system. Quite generally throughout the remainder of the Upper Peninsula the snowfall was either about normal or below it. In the Lower Peninsula Onaway showed a particularly heavy snowfall of 106 in., which is about 36 in. above its normal amount. In general throughout the remainder of the Lower Peninsula the amount of snowfall was about normal or below it. The lowest amount of snowfall shown in the state was that of 15.9 in. at Midland.

One remarkable feature of this winter's snowfall is shown in the fact that from a half to two-thirds of the entire winter snowfall came before the first of January, considerable snowfall in October, with very heavy amounts in November and December. At one station, namely Sault Ste. Marie, 0.2 in. of snow is shown for last September.

**Early Snowfall Increased Cost.**—Due to the fact that most of the snowfall occurred in the early part of the season, to a decreased amount, and to improved methods of snow removal, the cost of snow removal, especially in the heavier snow districts, has been considerably decreased. The minimum amount of cost is shown in Clinton County, where about 30 in. of snow was moved at a cost of \$6.27. The maximum cost was in Houghton County, where 108 in. is shown at Calumet and 125 in. at Houghton. The cost per mile is \$366.56.

A comparison of the snowfall up to the first of the year with the cost of snow removal over the same period

will at once impress the reader with the very great importance of the amount of snow on the ground at the time removal is done on snow removal cost. As has been stated, in a good many instances two-thirds of the snow fell before the first of January and this snow was moved at about a quarter of the cost for the entire season. The increased cost of snow removal in the later part of the season is due to several factors: first, as the amount of snow on the ground increases it becomes more and more difficult to widen out the roadways beyond accumulations of snow from previous work, next, when the ground is covered with snow cover, especially in the colder part of the season, drifting conditions are very much worse. As a matter of fact the amount of snow remaining on the ground throughout the various months gives a much better indication of what the cost of removal should be than does the amount of snowfall. The following table showing the average amount of snow on the ground in February of this year explains the reason for some of the higher costs. Only those stations were included where the amount of snow on the ground averaged more than 20 in. in depth:

Average Amount of Snow on Ground in February, 1927

Deer Park	47.7
Painesdale	42.2
Eagle Harbor	39.0
Humboldt	38.5
Twin Falls	38.0
Ironwood	34.5
Sidnaw	31.8
Munising	26.9
Cheboygan	26.5
Iron River (near)	25.8
Ruse (near)	25.2
Grayling	24.6
Alba (near)	24.0
Chatham	23.5
Ishpeming	22.0
Iron River	21.3
Newberry	20.6

The list given with only one exception covers those counties where the cost of snow removal exceeded \$150 a mile. There are several counties, however, included in this list whose record is considerably better than this. The effect of the amount of snow on the ground on snow removal cost is being investigated at the present time as it is felt that this factor, combined with the total snowfall, can more nearly express the amount of drifting than by any other means.

The seriousness of this drifting factor is affected to a considerable extent by the topography and culture of the country through which the work is being done. Long stretches of flat cultivated fields are by all odds the most difficult proposition to handle. Rolling wooded territory by reason of the lessened amount of drifting is reflected to a large extent in the snow removal costs. In a number of instances in the Upper Peninsula some removal work was done by bus companies carrying plows on the busses. This served to reduce the amount of snow removal cost in some counties.

**Continuous Method Effective.**—An analysis of these costs impresses one with the fact that the largest reduction in cost is shown by those counties which have adopted the continuous method of snow removal by truck patrol, reserving the heavy equipment for widening as far as possible. This method not only reduces the cost but gives a service which is incomparably better than the old method of waiting until the storm was over to move the snow.

Very great improvement has been noted during the past winter on the maintenance of the snow surface. Those roads visited during the past winter in the northern part of the state could be travelled with perfect comfort at summer speed. It is believed that the rough, rutted surface so often met in former years is unnecessary, and that its elimination is practically unnoticed in the total cost. That this is true is quite evident in the comparison of costs where the different methods are followed.

**New Developments.**—Several new developments in snow removal methods were brought out in the Cadillac Division by A. L. Burridge, Division Engineer. One of these was the plowing of snow traps in the field adjacent to the road to be cleared as a substitute for a snow fence. This method has reduced the cost considerably where used. Another new feature developed in this territory was the use of a cutting blade at the rear of a tractor in order to pull into the roadway high banks of snow to be removed by the rotary plow. This method enables the rotary to work to very much better advantage, as it can be used in banks of snow considerably higher than the rotors and only enough snow moved at a time so that the tractor can move along uniformly in second speed. The use of a spring blade used in gravel maintenance beneath the truck, which carries a "V" plow, has also resulted in high class maintenance of the snow surface with very little added cost.

The most remarkable showing made in the state on reduction of snow removal cost is that instanced in Gogebic County. At Ironwood this last winter, the official Weather Bureau record gives total annual snowfall as 115.5 in. There was in February of this year 34½ in. of snow on an average through the month at this station. The snow removal cost for this county over 89 miles averaged only \$95.60 per mile. This is truly a remarkable showing in view of the fact that in past winters the average cost of snow removal in this county has been well above \$200 per mile on roads covered by the snow removal program.

One of the striking features of this year's snow removal work is the fact that in Lower Michigan, at least, equipment and methods are becoming fairly well standardized and of nearly uniform efficiency. In one group of five counties in the central part of the state working under similar conditions, three of which are direct organization counties and two

of which are county maintained, it cost about \$18 per mile to move 30 in. of snow. These counties were apparently subjected to nearly the same snowfall and temperature conditions and the costs reported were almost exactly the same. It is felt that in the coming winter the introduction of more uniform methods throughout the entire state will bring these snow removal costs to a still closer relation to the actual climatic and cultural conditions under which the work is done.

### Shade Trees Along California State Highways

Some interesting information regarding the planting of shade trees along the state highways of California is given in the May issue of California



Tank Truck for Irrigating Trees in Operation

Highways by W. E. Glendenning, State Highway Arboriculturist.

Systematic tree planting for road beautification began in 1920. By 1922, 100 miles had been planted. At the present time, the Highway Commission is maintaining 56,400 trees on the state highways covering a lineal distance of approximately 685 miles. Generally the trees are spaced at 50-ft. intervals, being placed alternately on the right and left sides of the roadway with the necessary elimination for visibility at crossings and road intersections.

In addition to the above, a careful estimate of former planted and natural trees within the highway right of way gives a number far in excess of those listed, the care of which involves a project of considerable magnitude. This is usually assigned to the individual foreman. Assisting in the direction of this work is an arboriculturist reporting to the maintenance engineer. Special tree-watering equipment with movable discharge pipe has been developed which enables the watering to be performed from the driver's seat, a tank truck of 1,200 gal. usually being sufficient to water from 30 to 40 trees. Aside from irrigation and cultivation, many precautions are necessary for the protection of young trees against insect pests, damage by squirrels, gophers, moles and loose stock driven along the highway. The hazard of fire is also great.

Particular attention is given the location of the plantings with reference to the pavement so that it will present no

interference with its ultimate width. With this in mind, new plantings are discouraged on rights of way of less than 80 ft. In Division VIII, plantings adaptable to desert sections are propagated by the division itself. A small nursery has been established at the division headquarters at San Bernardino.

As load clearances require a clear height of 12 ft. above the pavement, systematic pruning and trimming is being followed to provide this clearance and at the same time develop a symmetrical, worth-while tree. Where power or telephone lines occur within rights of way planted to trees, the tree height is limited to 40 ft., and all trimming for wire clearance is done under permit and inspection, to the satisfaction of the Highway Commission.

The state itself makes no original plantings, but does not discourage plantings by civic or other public bodies. Trees are usually secured at a nominal price from the state nursery located near Davis. The planting and care of trees during the first year is handled by interested parties or the task may be assigned to state forces by the payment of a specific sum per tree planted and maintained. After the first year's maintenance, the state assumes the burden of care and replacement in event of loss of trees.

### Getting Ready for the Road Show

Work is progressing rapidly on the \$2,000,000 addition to the Cleveland Public Auditorium, where the Convention and Road Show of the American

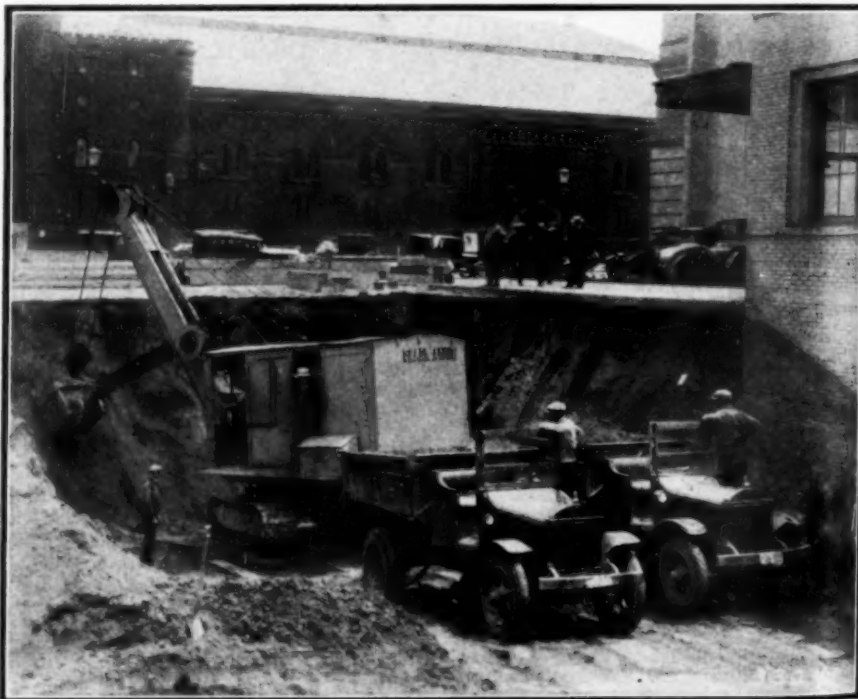
Road Builders' Association will be held next January.

The size of the present structure is approximately 200 ft. x 500 ft. and is located in the center of the block, between St. Clair and Lakeside avenues. The addition to each end of the present structure will make the public hall one block long. This will provide about 45 per cent more exhibition space than the association had at the Coliseum in Chicago.

The addition to the north end will be used to house conventions, etc., not large enough to warrant the use of the main building, while the addition to the south will be used for small theater groups.

The general contract for this work was let to the Hunkin-Conkey Construction Co. of Cleveland at a cost of approximately \$2,000,000. The excavation, which involves about 47,000 cu. yd., was sublet to Frank J. Smith, also of Cleveland, at a cost of approximately \$40,000. Sixteen hours after the contract was signed Smith had his 1-yd. Osgood on the job and promises to have his portion of the contract completed in good time.

**Course in Contracting in North Carolina College.**—W. C. Riddick, Dean of the Engineering School of North Carolina State College, has announced that a course in contracting will be opened this fall. The new course is the outgrowth of a request from the North Carolina Branch of the Associated General Contractors of America. The course as outlined will be very similar to the contracting course now being given at Yale.



View of the excavation on the north end, with the Central Armory in the background. This building will also be used to house the exhibits of the American Road Builders Association next January. The excavating contractor digs with a power shovel and the dirt is loaded into trucks for disposal.

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